ANALYSIS OF LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN® CONSTRUCTION IN THE AIR FORCE

THESIS

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Abstract

The Air Force uses the LEED rating system as a third party verification system to ensure sustainable and resource conscious facilities. The federal government has implemented several mandates in recent years that require certain milestones be met for energy reduction, water conservation, renewable energy use, and so forth. This research aims to determine how the Air Force has implemented LEED through credit analysis and to better understand why LEED is being used in this way.

Using a database of 172 military construction projects, this research evaluates the frequency of credit usage individually and by category. Interviews were conducted with subject matter experts to understand why specific credits were used, based on their ease or difficulty of achievement. Also, interview subjects were asked how to better implement LEED credits in hopes of meeting federal guidelines more effectively.

The most and least frequently used LEED credits were compared with the interview results. The more frequently used credits were often easier to achieve and the less frequently used credits were typically more difficult to achieve. The final recommendation is to require a stricter Air Force guideline indicating mandatory LEED credits to align with federal policies on new military construction projects.

To my Parents

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James M. Rozzoni

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ANALYSIS OF LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN® CONSTRUCTION IN THE AIR FORCE

I. Introduction

LEED Background

Created in 1998, the Leadership in Energy and Environmental Design (LEED) rating system for construction has grown to consult and certify over 14,000 projects in the United States and 30 countries worldwide with over 1.7 billion square feet of developed area. It was created and continues to be administered by the United States Green Building Council (USGBC). The certification system was designed in order to create a uniform framework for the design, construction, operations, and maintenance of green buildings which would make them sustainable as well as energy and cost efficient. The rating system provides third party certification to increase performance in energy savings, water efficiency, carbon dioxide emissions, indoor air quality, sustainable use of resources, and overall occupant satisfaction.

Originally conceived as an idea of the Natural Resources Defense Council (NRDC) in 1993, LEED was developed by scientist Robert K. Watson. Watson acted as founding Chairman of the LEED Steering Committee until 2006. Utilizing non-profit organizations, government entities, engineers, architects, developers, builders, and product specialists, the pilot program of LEED, version 1.0, was released in 1998. LEED v2.0 was released in 2000 and was slightly enhanced soon after resulting in v2.1, and the

most commonly used LEED v2.2. LEED v2.2 established a full system for evaluating construction for green and sustainable practices. The USGBC cites its mission as:

Market transformation through its LEED green building certification program, robust educational offerings, a nationwide network of chapters and affiliates, the annual Greenbuild International Conference and Expo, and advocacy in support of public policy that encourages and enables green buildings and communities.

To achieve this mission, the USGBC uses LEED to meet the following objectives:

- Define "green building" by establishing a common standard of measurement
- Promote integrated, whole-building design practices
- Recognize environmental leadership in the building industry
- Stimulate green competition
- Raise consumer awareness of green building benefits
- Transform the building market

Following LEED v2.2, USGBC adjusted the LEED system again and released the current iteration known as LEED 2009. LEED's requirements were criticized as confusing and hard to understand so the system consolidated some credits to include a range of possible points based on the percentage achieved for credits such as Water Efficiency Credit 3: Water Use Reduction. Credits are spread across six categories in v2.2 and seven categories in LEED 2009:

1. Sustainable Sites (SS): Focuses on the location on the project. Discourages the disruption of virgin land, rewards efficient transportation strategies, and minimizes impact on local ecosystems via reduced heat island effects and light pollution.

2. Water Efficiency (WE): Aims to minimize the use of potable water, landscaping water demand, and waste water generation.
3. Energy and Atmosphere (EA): Encourages enhanced commissioning, energy use monitoring, efficient energy use, the use of renewable energy (produced on and off site) and most importantly, overall energy use reduction.
4. Materials and Resources (MR): Aims to reduce the generation of waste during construction and operation, to use recycled, reused, and more sustainable materials in the construction effort.
5. Indoor Environmental Quality (IEQ): Promotes the most occupant satisfying environment including maximizing indoor air quality as well as thermal and light comfort levels.
6. Innovation in Design (ID): Credits earned by surpassing the requirements of the predefined credits or creating new and innovative techniques as determined by the USGBC.
7. Region Priority (RP): Unique to LEED 2009, features credits specific to regions of the United States and detailed on the USGBC website.

The first five categories have at least one prerequisite which must be earned in order to be LEED certified such as Sustainable Sites Prerequisite 1: Construction Activity Pollution Prevention. Table 1 shows a categorical point breakdown of each rating version. Table 2 shows the minimum points to achieve each rating version.

Table 1. Points per Credit Category for LEED v2.2 and LEED 2009

	LEED v2.2	LEED 2009
Sustainable Sites Points	14	26
Water Efficiency Points	5	10
Energy & Atmosphere Points	17	35
Materials & Resources Points	13	14
Indoor Environmental Quality Points	15	15
Innovation & Design Points	5	6
Regional Priority Points	N/A	4
Total Points	69	110

Table 2. Minimum Points per Rating for LEED v2.2 and LEED 2009

	LEED v2.2	LEED 2009
Platinum Rating	52	80
Gold Rating	39	60
Silver Rating	33	50
Certified Rating	26	40
Total Points	69	110

Green buildings are acknowledged as saving resources and cost through energy and water reduction as well as more efficient building techniques. The Green Building Alliance (GBA) of Pittsburgh, PA cites several such examples in its annual reports: $6,000,000 in total savings over the seven year lease for a furniture manufacturer (2003), $843,750 over the life of a government building that reached Gold LEED certification (2003), a Castcon-Stone manufacturing facility saved $150,000 in construction costs through the elimination of stormwater piping, and the David L. Lawrence Convention Center reuses 50% of its water and saves $500,000 in energy per year (2010).

Federal Policies

In 2005, the U.S. Congress enacted another edition of the Energy Policy Act (EPAct 05). EPAct 05 modified and enhanced policies of the original EPAct of 1992 which concentrated on alternative fuels and electric vehicles but included limited provisions for energy efficiency in buildings and renewable energy. EPAct 05 mandated much more stringent and specific energy and resource requirements for federal facilities to include the Department of Defense (DoD) and the Air Force. Overall energy consumption was to be reduced by two percent every year from 2006-2015 for a 20 percent reduction in all federal buildings. Also, facilities would "achieve energy consumption levels that are at least 30 percent below the levels established in the version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard or the International Energy Conservation Code" (EPAct 05, Section 109). Supplemental and essential to this measurement was Section 103 that mandated all federal buildings would be metered for utility usage by 1 October 2012. Future renewable energy goals and research is detailed along with the charge that federal facilities will use "(1) Not less than 3 percent in fiscal years 2007 through 2009. (2) Not less than 5 percent in fiscal years 2010 through 2012. (3) Not less than 7.5 percent in fiscal year 2013 and each fiscal year therefter." If renewable energy is produced and used on site, this counts double towards the renewable energy goals. The act defined renewable energy as "electric energy generated from solar, wind, biomass, landfill gas, ocean (including tidal, wave, current, and thermal), geothermal, municipal solid waste, or new hydroelectric" sources. These energy goals align with LEED 2009 credits in the Energy and Atmosphere Category including Credit 1: Optimize Energy Performance,

Credit 2: On Site Renewable Energy, Credit 5: Measurement and Verification, and Credit 6: Green Power.

Executive Order (EO) 13423, "Strengthening Federal Environmental, Energy, and Transportation Management," was signed in January of 2007. The order instructs all federal agencies on practices related to the environment, transportation and energy. It charges agencies and their directors to operate in "environmentally, economically, fiscally sound" ways and in a "sustainable manner." These instructions align directly with the goals and direction of EPAct 2005. EO 13423 includes the following goals:

- Reduce energy intensity by 30 percent by the end of FY15 relative to the FY03 baseline.
- Reduce water consumption by 16 percent by the end of FY15 relative to the FY07 baseline.
- 15 percent of existing Federal buildings will incorporate HPSB principles by the end of FY15.
- Reduce the use of toxic and hazardous materials and increase the reduction and diversion of solid waste.

These energy goals directly align with LEED 2009 credits in the Energy and Atmosphere Category including Credit 1: Optimize Energy Performance, Credit 2: On Site Renewable Energy, Credit 6: Green Power, all credits in the Water Efficiency Category, and credits in the Materials and Resources Category including Prerequisite 1: Storage and Collection of Recyclables.

Executive Order 13514, "Federal Leadership in Environmental, Energy, and Economic Performance," was signed in October of 2009. The order aims at reducing

greenhouse gas emissions and increasing renewable energy across all federal agencies. EO 13514 expands on EO 13423 and states its goal as "to establish an integrated strategy towards sustainability in the Federal Government and to make reduction of greenhouse gas emissions a priority for Federal agencies." EO 13514's goals include:

- Reduce potable water consumption by two percent annually through FY20.
- Minimize the generation of waste and pollutants through source reduction.
- Diverting 50 percent of non-hazardous and construction waste by FY15.
- Ensure that all new construction, major renovation, or repair and alteration of Federal buildings comply with the Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings.

These energy goals directly align with all LEED 2009 credits in the Water Efficiency Category and credits in the Materials and Resources Category including Prerequisite 1: Storage and Collection of Recyclables and Credit 2: Construction Waste Management.

In July 2007, Air Force Civil Engineer leadership created the Sustainable Design and Development (SDD) policy memorandum in order to outline how Air Force construction programs would carry out the mandates of EPAct 05, EO 13423, EISA 2007, and EO 13514. The policy mandated that all new vertical construction with climate control would be capable of achieving LEED Silver certification by FY09. According to the Energy Information Administration's Annual Energy Outlook (AEO) 2010, "Delivered commercial energy consumption is estimated to grow from 8.6 quadrillion BTUs in 2008 to 10.5 quadrillion BTUs in 2030." Air Force commercial style facilities

will theoretically follow this trend and present a resource saving opportunity for decades to come.

The SDD policy does not specifically require construction and design contractors to get official certification of facilities from the USGBC except for a small goal of 10 percent certification for applicable projects. Alternatively, all applicable Air Force construction projects are required to be "certifiable" according to the policy memorandum. The policy indicated a two percent program cost line item identified as "SDD & EPAct05" to account for sustainable practices, HPSB principles, and goals of EPAct05 and EO 13423 to align with LEED ratings. If the cost was to exceed two percent, an explanation would be required.

The Air Force Civil Engineer Support Agency (AFCESA) augmented the 2007 SDD policy by developing Engineering Technical Letter (ETL) 08-13 which offers several suggestions (not requirements) for renewable energy, utility metering, energy star rating, maintenance considerations, water conservation, occupancy sensors, and advanced Heating, Ventilation, and Air Conditioning (HVAC) systems. These instructions are recommended but are not necessarily required in construction. The ETL also reiterated the two percent cost factor in the programming amount of a project for federal requirements such as EPAct 05 and EO 13423 and the LEED Silver rating.

LEED Analyses

Miranda (2005) discusses ways to determine lowest cost credits by frequency of use and effectiveness from experienced construction. Keys to achieving low cost were cited as: developing clear realistic goals, assessing design teams abilities, knowing local

codes and regulations, establishing LEED rating early, staying focused, and conducting LEED design reviews at each phase of the project. Each level is progressively harder and more expensive so it essential to keep the end result in mind. Innovation in Design credits are easier than most people realize (20 percent water use reduction to 30 percent LEED v2.2), although some are extremely hard (20 percent renewable energy jumps to 40 percent, only 4 of 128 projects did this in the review). Miranda continues to list LEED points most often used: 127 earned LEED Accredited Professional, 121 earned Local/Region Materials, 119 earned Low Emitting Materials Carpet, 116 earned Recycled Content 5 percent, 112 earned Optimize Energy Performance 15 percent and so on. Miranda cites "Costs and Financial Benefits of Green Buildings: a Report to California's Sustainable Building Task Force" as stating there is a 0.7 percent increase for Certified, 2.1 percent increase for Silver, 1.8 percent increase for Gold, 6.5 percent increase for Platinum. The small sample size cannot be statistically relied on but still provides some notable findings.

In June 2008, the General Services Administration (GSA) conducted a case study of 12 sustainable buildings, seven of which received some level of LEED certification. The buildings were evaluated on energy use intensity, carbon dioxide emissions, water use, maintenance costs, Energy Star score, and occupant satisfaction. Baselines were the national average for all categories except for water use which was compared to the building design baseline. While on average the 12 buildings were able to improve on the national averages and baselines, the bottom third of the sample performed worse in the categories of water use and maintenance costs. The bottom third performed very close to average in terms of energy use intensity. Two of these buildings were Silver certified,

one was certified, and one was not certified. This report brings to light the fact that just because a building has achieved a certain LEED rating, it may not be energy efficient. Also, three buildings that used more water than the baseline were not LEED certified and one was Silver certified. This case study displays the results of LEED not measuring up to the desired resource savings.

Some credits of LEED have been interpreted as being more beneficial than others. "It appears that the (credits) providing the most environmental benefits are the one geared toward green power, reducing energy consumption, reducing commuting, increasing the recycling of wastes, and reusing the structure of the building during renovation" (Humbert el al. 2007). LEED buildings have been shown to use 18-39% less energy than traditional buildings (Newsham et al. 2009), however in that same sample of 100 LEED buildings, 28-35% used more energy than conventional ones. These benefits can be quite substantial: "financial benefits of green design are between $50 and $70 per square foot in a LEED building, over 10 times the additional cost associated with building green" (Kats, 2003).

Problem Statement

The Air Force must adhere to sustainability related federal mandates as well as internal goals. Also, a responsibility to the American people insists that the Air Force use its resources, money and energy, to the best of its ability. National fiscal limitations drive a need for the Air Force to create more efficient facilities in the near future as well. LEED provides a metric tool to quickly assess the attributes of facilities to determine

their ability for the Air Force to meet such requirements. However, LEED has a wide range of attributes that may or may not directly contribute to the desire result.

Research Questions

The objective of this thesis is to understand how LEED is being used to fulfill federal and internal Air Force sustainability goals. Also, subject matter experts will be interviewed to validate this data and determine what reasons there are for different credits and categories being used more or less than others.

The following is a list of specific questions and sub-questions used to guide this research:

1) How is LEED being used to meet Air Force goals?

    1.1: What credits are most and least used?

    1.2: What credit categories are most and least used?

2) Why is LEED being used in this manner?

    2.1: What credits are most and least difficult to achieve?

    2.2: What credits are the most and least beneficial in terms of energy and sustainability requirements?

3) What can the Air Force change to better implement LEED to achieve its goals?

    3.1: What policy changes would be beneficial?

    3.2: What design or construction process changes would be beneficial?

Altogether, this is an examination of the process in which new Air Force construction best meets sustainability goals. Question 1 and the sub-questions are to determine how LEED has been used in the recent past. Question 2 and the sub-questions

are to validate and better understand the results of Question 1. Lastly, Question 3 and the sub-questions aim to provide a recommendation for better LEED implementation.

Scope and Approach

This research seeks to evaluate a database of Military Construction (MILCON) projects for the Department of the Air Force as provided by the Air Force Center for Engineering and the Environment (AFCEE). Breakdowns of percent of projects earning specific credits, the average percentage of each credit category achieved, and the Spearman's rank correlation coefficient were used to quantitatively analyze how LEED is being implemented.

The qualitative methods in this research involve interviews which were conducted to validate and expand on the quantitative analysis. Human influence affects the way LEED is applied to construction projects in that there is a choice of which credits to include to reach a certain certification rating. The qualitative portion of this analysis helps to determine the nuances and human influence present in implementing LEED credits into sustainable design and construction.

Significance

As previously mentioned, several federal guidelines require sustainable construction and energy reduction be implemented in all new construction. In addition, according to the 2008 Air Force Infrastructure Energy Strategic Plan, the Air Force spends over one billion dollars on facility energy use annually, with more than two thirds of that cost coming directly from electricity. Reducing energy consumption will directly

reduce Air Force funding requirements. By assessing the progress of sustainable construction through an analysis of LEED credits, the Air Force can better implement LEED in the future. This research may help identify shortfalls in the application of LEED in order to create more sustainable and energy efficient infrastructure.

II. Scholarly Article

ANALYSIS OF LEED® CONSTRUCTION IN THE AIR FORCE

James Rozzoni, Peter Feng

Abstract

Research Question: How is LEED being used to help Air Force construction meet federal and internal sustainability goals?

Purpose: The purpose of this research is to better understand how LEED has been implemented and better understand the reasons behind the results.

Research Method: Quantitative analysis of project LEED data from 172 projects validated and expanded on with qualitative interviews of subject matter experts.

Findings: This paper determines what LEED credits and categories were most and least often used. Indoor Environmental Quality (IEQ) was the most prevalent category while Energy & Atmosphere (EA) and Materials & Resources (MR) were the least prevalent. Interview subjects validated these results by agreeing that IEQ credits were in general easier to achieve, yet EA credits are generally the most beneficial.

Limitations: The research considers new, Air Force, vertical, construction projects with climate control between 2005 and 2011.

Implications: The research indicates a need to reexamine the application and policies pertaining to the application of LEED on new Air Force construction projects.

Value for Practitioners: This paper will help identify shortfalls in the requirements for the design and construction of Air Force sustainable facilities.

Keywords: green construction, sustainability, sustainable design, energy, LEED

Paper type: Full paper

Introduction

The Leadership in Energy and Environmental Design (LEED) rating system, developed by the United States Green Building Council (USGBC), is a credit based scoring system used to provide a standard metric for sustainable facility design, construction, and operation. Since 2005, the Air Force has used LEED on vertical construction projects with climate control and as of 2011 requires Silver Certification on all new construction.

Several federal mandates, such as the Energy Policy Act of 2005 (EPAct 05), Executive Order (EO) 13423, 13514, and the Energy Independence and Security Act of 2007(EISA 2007) require certain energy savings, water use reduction, and other sustainable goals be met by new Federal buildings. While these mandates are environmentally driven, budget cuts also warrant a reduction in resource spending.

The following article presents a breakdown of how the Air Force has gone about achieving LEED and attempts to determine some reasons behind the findings. Objectives, limitations of the data, and the research question will be explained. The methods of interviewing will be discussed, as well as how the project database was analyzed. The project database and credits earned will be explained, and finally the interviews will be summarized to show reasoning behind the credit information. Lastly, recommendations and conclusions will identify the overarching issues and possible solutions for the Air Force to enact.

Objective

The objective is to understand how the Air Force has implemented LEED and what shortfalls may be occurring. The metrics of percent of projects earning each credit, average credits earned per category, and Spearman's rank correlation coefficient allow us to analyze the project data and determine where emphasis is being placed. These metrics will show generalities in the application of LEED and can be further explored with the knowledge of subject matter experts.

Limitations

This research is subject to several boundaries. The dataset is limited to new Air Force vertical construction projects with climate control from 2005-2011 encompassing various phases of development from initial design to beneficial occupancy. Housing and modification projects were excluded due to their different LEED rating systems. Data on the projects was input by AFCEE project managers and is subject to human error in various steps of data entry and communication. The LEED categories of Innovation & Design (ID) and Regional Priority (RP) are only briefly mentioned as their differences in how they are achieved vary greatly between projects.

Further limitations are encountered in the interview process. Subjects were limited to a small sample size and proximity to the researcher. A small sample size of interviews may influence results with individual biases from the interview subjects as well as limitations in the scope of their project experience.

Research Question

The Air Force Sustainable Design and Development (SDD) policy memorandum of 2007 outlines that Air Force construction projects will utilize LEED to:

1. Reduce environmental impact
2. Reduce total ownership cost of facilities
3. Improve energy efficiency and water conservation
4. ~~Provide safe, healthy, and productive built environments~~ (Not considered in this study)

Has the implementation of LEED been able to meet the goals of policies set by the Federal Government and Department of the Air Force? This article will delve into this issue through several questions and sub-questions.

1) How is LEED being used to meet Air Force goals?

    1.1: What credits are most and least used?

    1.2: What credit categories are most and least used?

2) Why is LEED being used in this manner?

    2.1: What credits are most or least difficult to achieve?

    2.2: What credits are the most and least beneficial in terms of energy and sustainability requirements?

3) What can the Air Force change to better implement LEED to achieve its goals?

    3.1: What policy changes would be beneficial?

    3.2: What design or construction process changes would be beneficial?

Methods

This section presents the methodology used for data collection and subsequent analysis of credits achieved on Air Force Military Construction (MILCON) projects. The Air Force Center for Engineering and the Environment (AFCEE) provided LEED data for 172 MILCON projects along with other various attributes to include: square footage, usage, and location. With Federal and Air Force policy goals in mind, beneficial and non-beneficial LEED credits were identified through qualitative interviews. Also, more and less difficult credits were determined in the opinion of the interview subject. These credits were then compared to the project data in order to determine value similarities in construction execution.

Input will be gathered qualitatively by interviewing decision makers in the management, design, and construction of a facility. Interview subjects are to include: two design engineers specializing in LEED construction, an Air Force LEED program subject expert, a construction manager with LEED construction experience, a federal facility engineer with experience in LEED construction, and a design firm Vice President with LEED projects. Credits will be chosen based on the ease in which to attain them, to include design simplicity, ease of construction, ease of upkeep, and other inputs from the interview subjects.

Interviews were selected as the appropriate qualitative methodology because of the uncertain nature of construction and design execution (Smith et al. 2009). The differences between projects is so great across the span of facility type, size, location, contract method, mission priority, material constraints, and more generate a complicated and difficult problem when it comes to identifying individual factors that contribute or

take away from sustainable and resource saving capability. An in-depth interview will help with this open ended question: "The goal is to have the participant reconstruct his or her experience within the topic under study" (Seidman, 2006: 15). Through the subject matter experts, this research aims at finding the best results of beneficial and non-beneficial LEED credits for the comparison with the existing database.

Seidman suggests following the three interview model which involves a series of approximately 90-minute interviews three to seven days apart. This allows for establishing interview subject context and history, reconstruct the details, and finally reflect on the meaning of the experience. For the purposes of this research, the interview process will be shorter in duration and encounters. Two interviews will be accomplished with a month in between. The first interview will concentrate on the subject's background in facilities, their understanding of LEED and its application, what credits are beneficial, non-beneficial (in the aims of Federal and Air Force resource and sustainable goals), and what credits are hardest or easiest to attain . The second interview will focus on the application of LEED in the Air Force and recommendations for better implementation. Seidman generally accepts this modification to the three interview process, "As long as a structure is maintained that allows participants to reconstruct and reflect upon their experience within the context of their lives, alterations to the three interview structure and the duration and spacing can certainly be explored" (Seidman, 2006: 21).

Seidman explains the techniques and pitfalls throughout his book. The issues and instructions presented are almost all specific to a face to face interview. The instructions should be simplified and the pitfalls should be avoided through the use of an e-mail based

interview. Subjects will have ample time to think through their responses. Body language and interview interruption will be eliminated as a variable, differences between social group identities of the researcher and the subject will be minimized, and recording of results will be simplified. Subjects will be given the rights deserving of them including, but not limited to, the option to withdraw at any time, the option to mask their identity, and access to the data and results as developed by the researcher.

The quantitative portion of research is described in the following.

1. A data call from AFCEE was conducted in fall 2010 for cost, LEED credits, Federal Requirements for High Performance Sustainable Buildings (HPSB) data, and more. These spreadsheets contained the LEED credits achieved or that were to be achieved on each project.
2. 184 excel files were received detailing project information to include the credits achieved or intended to be achieved. Duplicates, housing projects, minor construction, and incomplete files were then removed leaving 172 projects, 119 using LEED v2.2 and 53 using LEED 2009.
3. The total number of projects that attained each specific credit was tabulated and documented in a consolidated spreadsheet. The number of projects that attained each credit was divided by the total number of projects to provide a percentage of projects meeting a number of points in each credit. Several adaptations were needed to account for the differences between LEED v2.2 and LEED 2009.
    a. Sustainable Sites (SS) Credits 2, 4.1, 4.3, 4.4 have been expanded from 1 possible credit point to multiple credit points in LEED 2009. While the number of points for these credits has increased, each credit is considered

a binary decision of achieved or not achieved. For this analysis, LEED v2.2 and LEED 2009 credits for Sustainable Sites have been fused together into simply achieved or not achieved without regard for number of points.

b. Water Efficiency (WE) Credits were realigned so that LEED 2009 contained a prerequisite credit of 20% water use reduction that did not exist in LEED v2.2. In v2.2, the 20% reduction was captured in Credit 3 for one point. For this analysis, the 20% reduction credit point was fused with the prerequisite from LEED 2009. Credits 1.1, 1.2 and 2 referring to Water Efficient Landscaping and Innovative Wastewater technologies increased from 1 to 2 points each but were counted simply as achieved or not achieved. Credit 3: Water Use Reduction, was broken into 3 categories: 30%, 35%, and 40% reduction as in LEED 2009. LEED v2.2 Credit 3 point credits for 30% reduction were fused with 30% reduction from LEED 2009 for this analysis. Reductions of 35% and 40% were also counted, however only were achieved in LEED 2009.

c. The elements of the Energy and Atmosphere (EA) credit category are virtually the same between LEED v2.2 and LEED 2009. The only difference comes in the range of points in energy savings or provided by renewable energy. Credit 1: Optimize Energy Performance was increased from 10 points to 19 in the newer system, and expanded the percentage of energy savings from a range of 10.5% through 42% to 12% through 48% in the newer system. Credit 2: On-Site Renewable Energy was increased

from three to seven point but maintained a similar range of requirements. For the purpose of determining the percentage of projects that achieved these two credits, percentages that were equal or within 0.5% between the subsets of LEED v2.2 and LEED 2009 were merged and tabulated. LEED 2009 unique values were calculated out of the 53 possible projects. All other credits within the EA category remained the same but increased their number of points possible. These credits will be counted as simply binary: achieved or not achieved credits disregarding their point values. The remaining credits in the EA category are merged into one percentage calculation per credit for both versions of LEED.

d. Materials and Resources (MR) credits are similar between LEED v2.2 and LEED 2009 except for Credit 1.1: Building Reuse, Maintain Existing Walls, Floors, and Roof. LEED 2009 adds an additional point to the credit for maintaining 55% of Existing Walls, Floors, and Roofs. Points in LEED v2.2 were for maintaining 75% and 95%. This percentage was calculated, and cumulative totals for the maintaining of these materials are included to cover the new 55% point. This credit is attributed to renovation projects and is not a significant factor in the research of this thesis. The remaining credits in the MR category are merged into one percentage calculation per credit for both versions of LEED.
e. Indoor Environmental Quality (IEQ) credits are identical between LEED v2.2 and LEED 2009. All credits in this category are merged into one percentage calculation per credit for both versions of LEED.

f. Innovation and Design Process (ID) Credits are mostly unchanged between the versions. LEED 2009 increased ID points from four possible to five. Both versions still contain the LEED Accredited Professional credit (1 point). The additional ID point is calculated only for LEED 2009 projects. The common credits in this category are merged into one percentage calculation per credit for both versions of LEED.

g. Regional Priority (RP) credits were added in LEED 2009 but did not exist in LEED v2.2. The four possible points are calculated by percentage of projects attaining them in the LEED 2009 rating scale and excluded for LEED v2.2 projects.

4. The average number of points per credit category was calculated for all projects. Different scales between the versions of LEED warranted a separation in this calculation. The average number of points per credit category was determined for each LEED version to show how the average project in each version was going about attaining its LEED rating. The comparison between LEED v2.2 (projects initiated prior to 2009) and LEED 2009 (projects initiated in 2009 or later) also provides a change over time of which credit categories were more likely to be used in a project. Using the statistic analysis software JMP version 9.0, Spearman's ρ (rho) rank-based correlation coefficients were calculated. It is considered a "classical sample correlation coefficient applied to the rankings of the X and Y observations within their respective samples" (Hollander and Wolfe, 1973). This correlation coefficient will indicate which credit categories have a tendency of being earned more often on projects earning higher total points.

Analysis and Results

Figures 1 and 2 show the credit breakdown of the Air Force LEED projects within the data set. The darker bar indicates the credits possible in each credit category. The lighter bar indicates the average number of credits achieved across the range of projects documented. The separation between the heights of the bars indicates how well that category was utilized with a smaller separation indicating more utilization. The largest disparity occurs in the EA category which provides energy savings throughout the lifecycle of a project. Projects only averaged 7 points of 17 possible for a 41% utilization rate in LEED v2.2 and averaged 12.5 points of 35 possible for a 36% utilization rate in LEED 2009. Conversely, WC performs better with projects achieving an average of 3.3 points of a possible 5 points for a 66% utilization rate in LEED v2.2 and 5.7 points of a possible 10 points for a 57% utilization rate in LEED 2009. While not a major cost factor at this time, water conservation is vitally important in dry regions of the country as well as in times of drought. IEQ has a relatively high rate of utilization at an average of 9.7 points of 15 possible for a 65% utilization rate in LEED v2.2 and rises to 10.8 points of 15 possible for a 72% utilization rate in LEED 2009. This category has certain implications on personnel productivity levels, it does not provide direct cost savings to the Air Force which are greatly needed in anticipation of future defense spending limitations. The decline of EA and WC credits from LEED v2.2 to LEED 2009 can be interpreted as a change over time as LEED 2009 projects are more recently than LEED v2.2.

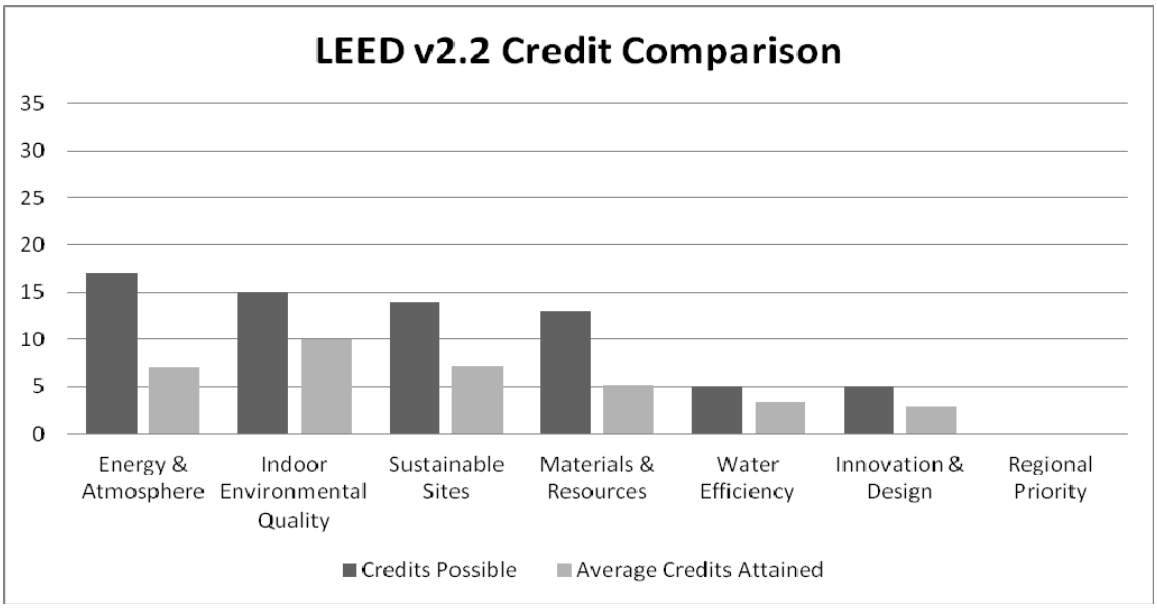


Figure 1: LEED v2.2 Credits Possible v. Average Credits Attained

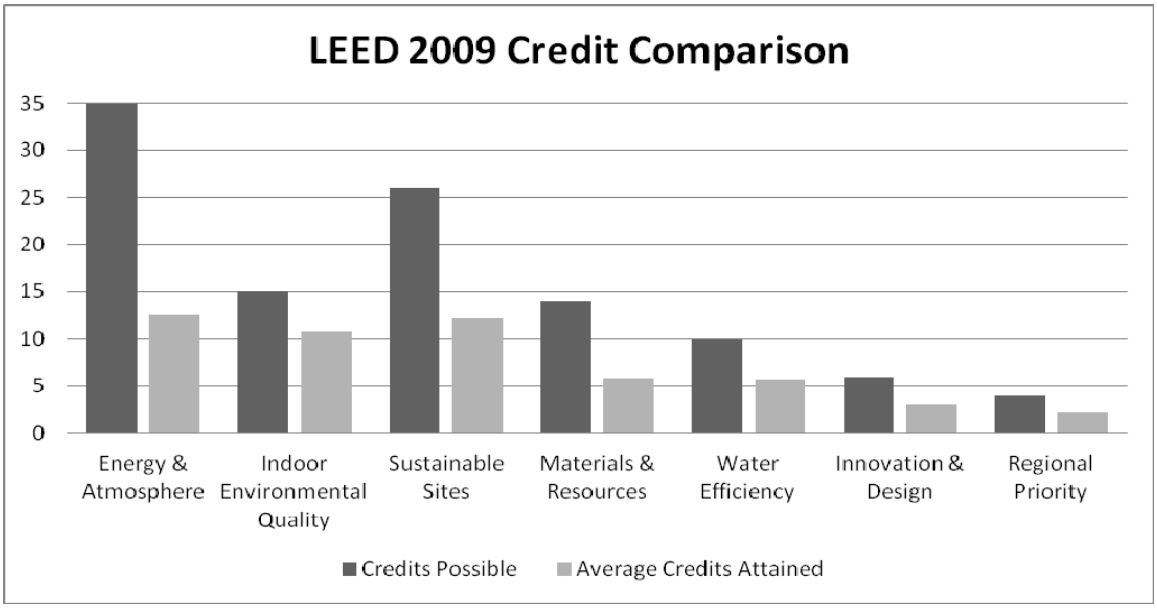


Figure 2: LEED 2009 Credits Possible v. Average Credits Attained

Of the interviews conducted, there are several discernible similarities between subjects as well as a few differences. The SS category had several credits identified as most or least beneficial and most or least difficult but without clear standouts. SS Credit 7.1: Heat Island Effect – Non-Roof, SS Credit 7.2: Heat Island Effect – Roof, and SS

Credit 8: Light Pollution Reduction were identified as beneficial to reduction goals, although SS Credit 8 was also mentioned as not beneficial. Several credits including SS Credit 2: Development Density & Community Connectivity, SS Credit 5.1: Site Development, Protect or Restore Habitat, SS Credit 5.2: Site Development, Maximize Open Space, SS Credit 6.1: Stormwater Design, Quantity Control, and SS Credit 6.2: Stormwater Design, Quality Control were identified as being difficult to achieve. All four sub-credits under the SS Credit 4: Alternative Transportation as well as SS Credit 1: Site Selection were identified as being least difficult to achieve. Within the dataset, projects utilized the following credits between 65% and 75% of the time: SS Credits 4.2, 4.3, 4.4, 5.2, 6.1, 7.2, 8. Also, SS Credit 1 was used on over 90% of the projects. The only credits within the Sustainable Sites category to be used on less than 20% of the projects were SS Credit 3: Brownfield Redevelopment (9%) and SS Credit 5.1: Site Development, Protect or Restore Habitat (18%).

In the WE category, most points were viewed as beneficial to Federal and Air Force water usage reduction goals. Specifically, WE Credit 1.1: Water Efficient Landscaping – Reduce Potable Water Use by 50% and WE Credit 3: Water Use Reduction were considered the most beneficial. Nearly all projects in the sample were able to integrate WE Credit 1.1 and WE Credit 1.2: Water Efficient Landscaping - No Potable Use or No Irrigation was used by almost 66% of the dataset. Nearly 70% of the projects were able to incorporate WE Credit 3: Water Use Reduction - 30% Reduction (2 points), however only around 10% were able to reach further to the 35% (3 points) and 40% (4 points) reduction levels. None of the WE credits stood out drastically as difficult or easy to obtain, however they were considered slightly more easily attained than not.

All subjects interviewed agreed that EA Credit 1: Optimize Energy Performance and EA Credit 3: Enhanced Commissioning are the most beneficial to reducing energy consumption. More than 90% of projects in the sample were able to reduce energy consumption by 17.5% below baseline via EA Credit 1; however this declines to only around 42% of projects achieving 31.5% below baseline despite the Federal and Air Force goals of a 30% below baseline energy usage. EA Credit 3: Enhanced Commissioning was used on about 33% of projects in the sample. These credits were also viewed as being difficult to achieve. EA Credit 2: On-Site Renewable Energy was the most commonly identified difficult credit between the interview subjects. Only around 10% of projects in the sample size utilized On-Site Renewable Energy, with none of the projects pulling more than 5% of their building's usage from On-Site Renewable sources. EA Credit 6: Green Power was identified as an easier credit to achieve and was utilized on only about 12% of the sample projects.

Within the MR category of credits, few points were included by the interview subjects as difficult or easy and beneficial or not. One subject indicated that MR Credits related to Recycled Content, Regional Materials, Rapidly Renewable Materials, and Certified Wood (MR Credits 4-7) were not beneficial to the goals aforementioned in this article. Also, MR Credit 6: Rapidly Renewable Materials was considered difficult to attain. MR Credit 2: Construction Waste Management (Divert 50% or 75% from Disposal) was utilized by around 35% of projects. MR Credit 4.1: Recycled Content, 10% was used by more than 97% of the projects and MR Credit 4.2: Recycled Content, 20% was used by more than half of the projects. MR Credit 5, Regional Materials was used by around 50% of the projects, and Credit 7: Certified Wood was used by more than

69%. All other credits within the MR Category were used by less than 10% of projects in the dataset, although most are only applicable when new construction is placed on the site of an existing structure.

The IEQ Category had various responses from the interview subjects. IEQ Credit 1: Outdoor Air Delivery Monitoring and IEQ Credit 6.1: Controllability of Systems, Lighting were noted as beneficial for Federal and Air Force goals. IEQ Credit 4.1-4.4: Low Emitting Materials were noted as not beneficial. Also, those same credits were identified as easier to achieve. In addition, IEW Credit 3.1: Construction Indoor Air Quality Management Plan, During Construction, IEQ Credit 5: Indoor Chemical and Pollutant Source Control, and IEQ Credit 7.2: Thermal Comfort Verification were identified as less difficult to achieve. IEQ Credits 1, 3.1, 3.2, 4.1, 4.2, 4.3, 4.4, 6.1 and 7.1 were all shown to be used in more than 80% of the projects in the data set. Only IEQ Credit 2: Increased Ventilation and IEQ Credit 8: Daylight & Views were used on less than 35% of projects.

A follow up interview was conducted with the same interview subjects to ascertain their take on several issues facing LEED implementation in the Air Force. This interview was assessed some four weeks after the initial interview to give subjects time to further develop their thoughts on LEED in the Air Force, as prescribed by Seidman. Questions were aimed at determining the success of LEED in terms of a third-party verification system (as outlined by EISA07), achieving the multiple federal and internal goals, as well as the effect of the new 2011 Air Force Civil Engineer Policy of full Silver Certification and mandatory 20 points from specified energy and water credits.

All interview subjects answered positively about the benefit of LEED as a third party verification system for new construction in the Air Force. Specifically, interview subjects mentioned LEED certification as "standardized," "independent," "peer reviewed," and "relates what the Air Force does to the industry at large." These terms directly relate to criteria for a third-party system outlined by EISA07 [Section 433, part (a) clause (iii)] such as "independently verify the criteria and measurement of metrics," "the ability of the standard to be developed and revised through a consensus-based process," and "national recognition within the building industry."

Interview subjects were asked if the federal goals outlined by EPAct05 and E.O. 13423 to achieve energy reduction of 30%, water use reduction of 16%, and renewable energy use of 7.5% will being met by the new Air Force Civil Engineer policy memorandum outlining that projects will earn 20 specified credits from a 50 credit specified energy and water conservation list (see Appendix D). One interview subject highlighted the fact that the energy reduction goal is already specified in Request for Proposal (RFP) documents so it is a mute point. As well, water reduction often far exceeds 16% automatically. Thus, projects will often receive enough credits to reach the 20 credits required by the policy memo without touching the renewable energy use goal. Another interview subject responded with a similar analysis, pointing out that a project could earn 19 credit points from EA Credit 1, and one credit point from anywhere else (not related to water or renewable energy), and therefore miss two of three goals. Another interview subject agreed stating that "If you build to current building codes, you easily reach the 20 point goal and do nothing to push the envelope." The interview

subject emphasized the fact that this leaves little room "for things like Renewable Energy, Green Power, Daylighting and Views, Measurement, and Verification."

Lastly, interview subjects were asked to summarize what corrections could be made in terms of sustainable policy, the design process, and the construction process. One respondent explained that integrated design was essential to the success of sustainable buildings and that current Air Force procurement methods prevented "innovative sustainable solutions." Also, there appears to be no incentive for design firms to innovate and create more sustainable and efficient projects. Another respondent indicated that while policy may be enough, the education must be present to reinforce the requirements and how to show compliance. Also, "project and requirement definition" is the "most critical piece here, but again, education goes into play." Lastly, the respondent commented that Quality Control and Inspection during the construction process is a major factor. The specific example of air barrier was mentioned as showing an increased rate of compliance when the contractor is informed of an impending inspection. A different respondent highlighted that while effective, LEED requirements are often barred from implementation in the Air Force due to stagnant practices such as roof color and custodial restrictions. Also, changes will come about in the next version of LEED such as the "Eco-Charrette", which will require more integration in the design process. Another respondent suggested moving to a Gold standard of LEED certification to include minimum energy reduction point values.

Table 3 gives the Spearman's ρ for each credit category by LEED version. Asterisks indicate coefficients that were not statistically significant using a 90% confidence interval. LEED v2.2 provides more significant results, expectedly due to the

larger data set. The SS and EA categories in LEED v2.2 have a higher correlation than the rest of LEED v2.2 indicating they are more often used in projects earning more overall points. There is a stark change to LEED 2009. SS's correlation becomes even higher while EA's correlation decreases drastically. However, EA's LEED 2009 correlation is not statistically significant. This decrease in EA's correlation indicates its lack of use when projects tend towards higher credit ratings. Also, MR and IEQ credits show an increase and proved to be significant. This increase may be indicative of projects utilizing less beneficial credits when a higher LEED rating is desired.

Table 3: Spearman's Rank Correlation Coefficients

	LEED v2.2		LEED 2009	
	Spearman ρ	Prob > ρ	Spearman ρ	Prob > ρ
SS	0.4071	< 0.0001	0.6586	< 0.0001
WE	0.2326	0.0109	0.1163*	0.4069
EA	0.4832	< 0.0001	0.1562*	0.2641
MR	0.2993	0.0009	0.3905	0.0038
IEQ	0.2386	0.0090	0.3464	0.0111
ID	0.2165	0.0180	0.1270*	0.3647
RP	NA	NA	0.1797*	0.1979

For a full breakdown of credits by percentage earned, see Appendix A. For a full breakdown of credits by category, see Appendix B. For the JMP outputs regarding Spearman's Rank Correlation Coefficient, see Appendix C.

Recommendations and Conclusions

As of June 2011, Air Force Civil Engineer leadership and AFCEE have created an additional policy memorandum to mandate full Silver certification and minimum credit requirements to meet new Federal High Performance and Sustainable Building guiding

principles, specifically to reduce energy and water consumption. A minimum of 20 points must be achieved from a list of credits specific towards saving energy and water as seen in Appendix D. Considering LEED 2009 includes 35 EA credits and 10 WE credits, the design engineers or construction managers can include a wide variety of these credits on a LEED Silver certified facility and not necessarily choose the credits best suited to Federal and Air Force goals of sustainability and resource consumption reduction. Also, of the 50 credits required for Silver Certification, the remaining 30 credits may not contribute to the goals previously mentioned.

LEED certification presents many avenues to sustainable facilities and the conservation of resources. Air Force LEED implementation provides a standard metric for ensuring that facilities are utilizing different techniques aimed at meeting federal mandates. Also, LEED facilitates energy reduction which can be directly attributed to cost savings. The need for cost cutting is more important than ever during the current fiscal climate. The results of this data analysis reveal an apparent overuse of IEQ credits and a lack of EA credits. Through subject matter expert interviews, this discovery is generally attributed to the ease of with IEQ credits are earned, and the difficulty of certain EA credits.

Through this research, a deficiency in policy and project execution has been identified. The recommendation, based on sustainability goals previously identified, is that Air Force new vertical construction with climate control must meet energy reduction requirements of 30% lower than ASHREA standards, 30% water use reduction below standard baseline, and that 7.5% of energy will come from renewable sources (on or off site) as defined by EPAct05. These metrics must be verified no earlier than a year after

beneficial occupancy to ensure proper compliance. This can be accomplished by requiring WE Credit 3 (2 points), EA Credit 1 (10 points), EA Credit 2 (3 points) or EA Credit 6, and EA Credit 3 to ensure compliance through verification. Monetary Incentive for builders should also be considered.

This analysis of LEED yields a few recommendations for future Air Force policies regarding implementation of LEED. The total programmed amount for the projects in this study is over 3.5 billion dollars. From the 2% figure from ETL 08-13, around 70 million additional dollars will have been spent on LEED and HPSB requirements. The credits earned by these projects in this database may not translate to reduced energy and greater sustainability for the Air Force. Thus, a more in depth and specific policy should be implemented to better capture the benefits that LEED can provide.

Bibliography

The references of this article are combined throughout the thesis and can be found following the appendixes.

III. Conclusion

Chapter Overview

This chapter discusses the research findings related to the original questions discussed in Chapter 1. The scholarly article communicates the prominent results of the research. However, the article does not include expanded discussion of the results and greater implications for the future. This chapter first briefly reviews the findings with respect to the questions that generated the research. The significance of the research is then discussed. Finally, future research and a summary of the research form the concluding portion of the thesis.

Review of Findings

The three research questions asked in this research inquire as to 1) How LEED is being implemented in the Air Force, 2) Why LEED is being implemented in such a manner, and 3) What can be changed to better implement LEED in the Air Force. The sub-questions offer specifics of those questions in a more accountable way. The discussion below provides a summarized review of the answers discovered through this research.

1) How is LEED being implemented:

Through the quantitative data analysis, the credit utilization rate was calculated for each individual credit, as well as each credit category. Of the possible EA credits, 41% are utilized in LEED v2.2 and 36% in LEED 2009. Of the possible WE credits, 66% are utilized in LEED v2.2 and 57% in LEED 2009. Of the possible IEQ credits, 65% are utilized in LEED v2.2 and 72% in LEED 2009.

The top 20 more commonly used credits is dominated by IEQ credits, EA Credit 1 (when reducing energy up to 21%), prerequisite credits for various categories, and a few MR credits. However EA Credit 1, reducing 30% or more energy use, is the 42nd most often used credit, only being used on approximately 64% of projects. The least most commonly used credits were EA Credit 1 when reducing over 34% energy use, EA Credit 2: On-site renewable energy, and various MR credits, mostly related to construction utilizing existing structures. Spearman's rank correlation coefficient indicates that SS and EA credits are used on higher rated LEED v2.2 projects, however EA falls drastically in LEED 2009.

2) Why LEED is being implemented in this manner:

Subject matters experts were able to identify several credits as being easier or harder to achieve, as well as being more or less beneficial in terms of sustainability and resource savings. Underutilized credits such as EA Credit 1, when reducing more than 30%, EA Credit 2, On-site renewable energy, and EA Credit 3 Enhanced Commissioning were in fact interpreted by the interview subjects as being difficult to achieve. Conversely, EA Credit 6: Green Power was only used on 12% of projects despite being considered easy to achieve. EA Credit 1, 2, and 3 are considered more beneficial for resource savings as well as most Water Conservation credits.

3) Suggestions for improvement:

LEED was confirmed as a suitable third party verification system by the Subject Matter Experts. The new policy memorandum from Air Force Civil Engineer leadership can easily be achieved although leaves many credits to the discretion of the contractor. Also, 20 credits are almost automatic through current construction practices. The

solutions for improving the use of LEED were generally simple. Education of involved parties, emphasize sustainability throughout design and construction, and quality control were seen as effective ways to provide achieve sustainability goals.

Significance of Research

The research conducted in this study is pertinent to the Air Force and the government as a whole. Projects in this database are programmed at over 3 billion dollars, with some 70 million of those dollars being allocated for LEED and HPSB requirements. These funds will ideally pay for themselves over years of resource savings, but LEED implementation must be carried out in a certain way to ensure this. In fact, this 2012 fiscal year military budget includes reduction of some 43 billion dollars from the previous year (National Defense Authorization Act for Fiscal Year 2012). This research effort is necessary to determine in what way LEED has been implemented and if changes are required for more effective usage.

Future Research

While this study explains the general terms in which the Air Force has achieved sustainable construction. There are many other specific facets that should be explored however. Possible topics are as follows:

- Analysis of costs related to different LEED certification levels.
- Lifecycle cost analysis comparing Air Force LEED and non-LEED buildings.

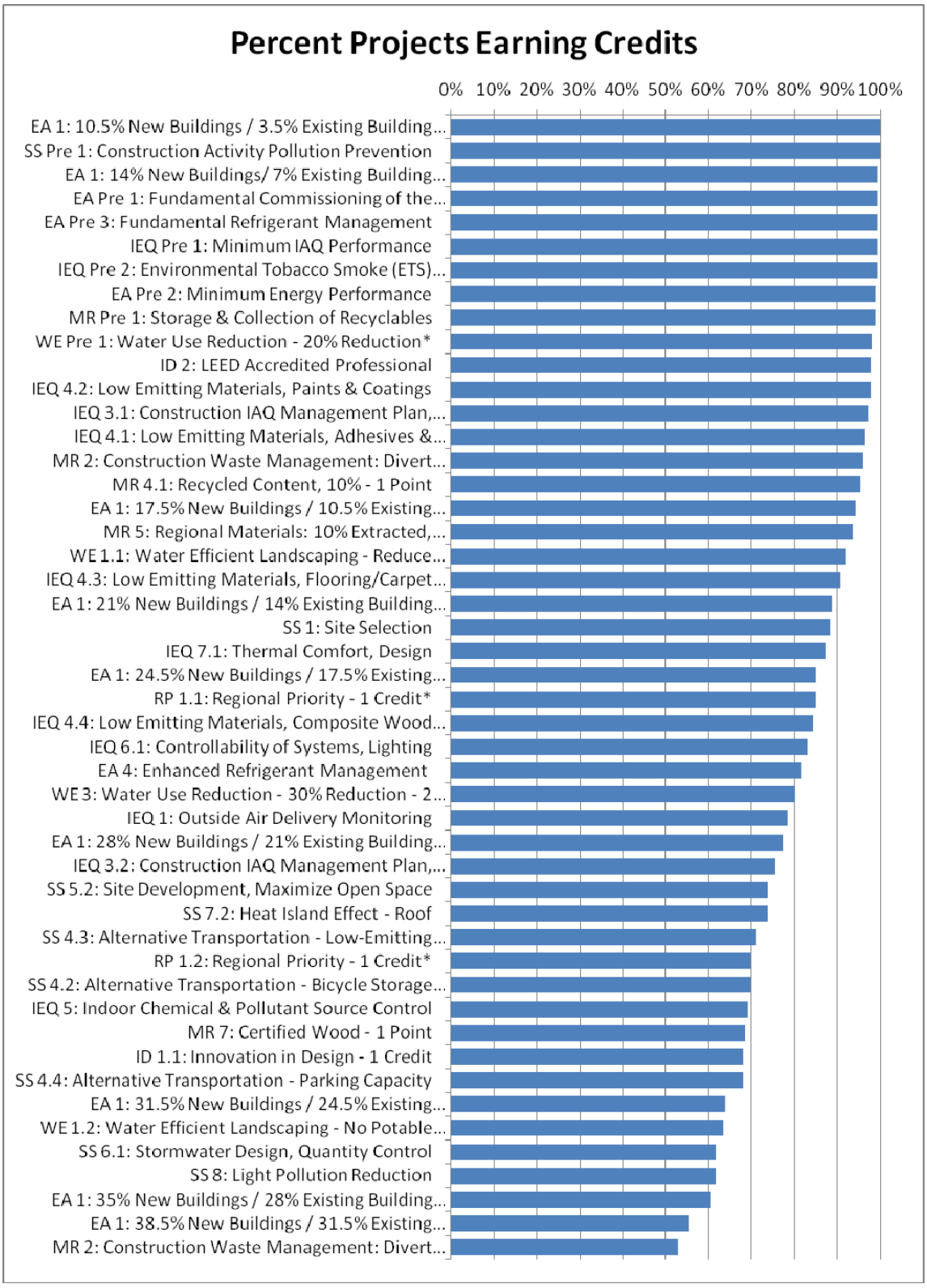
- Resource usage, occupant satisfaction and productivity, and maintenance cost case studies.
- Trends in LEED for Air Force commands, building types, size, etc.

This research has identified what LEED credits and categories are being used the most and least frequently. The next step is to discover the impacts of using specific credits in terms of sustainability, water and energy conservation, and impact on occupant productivity and health.

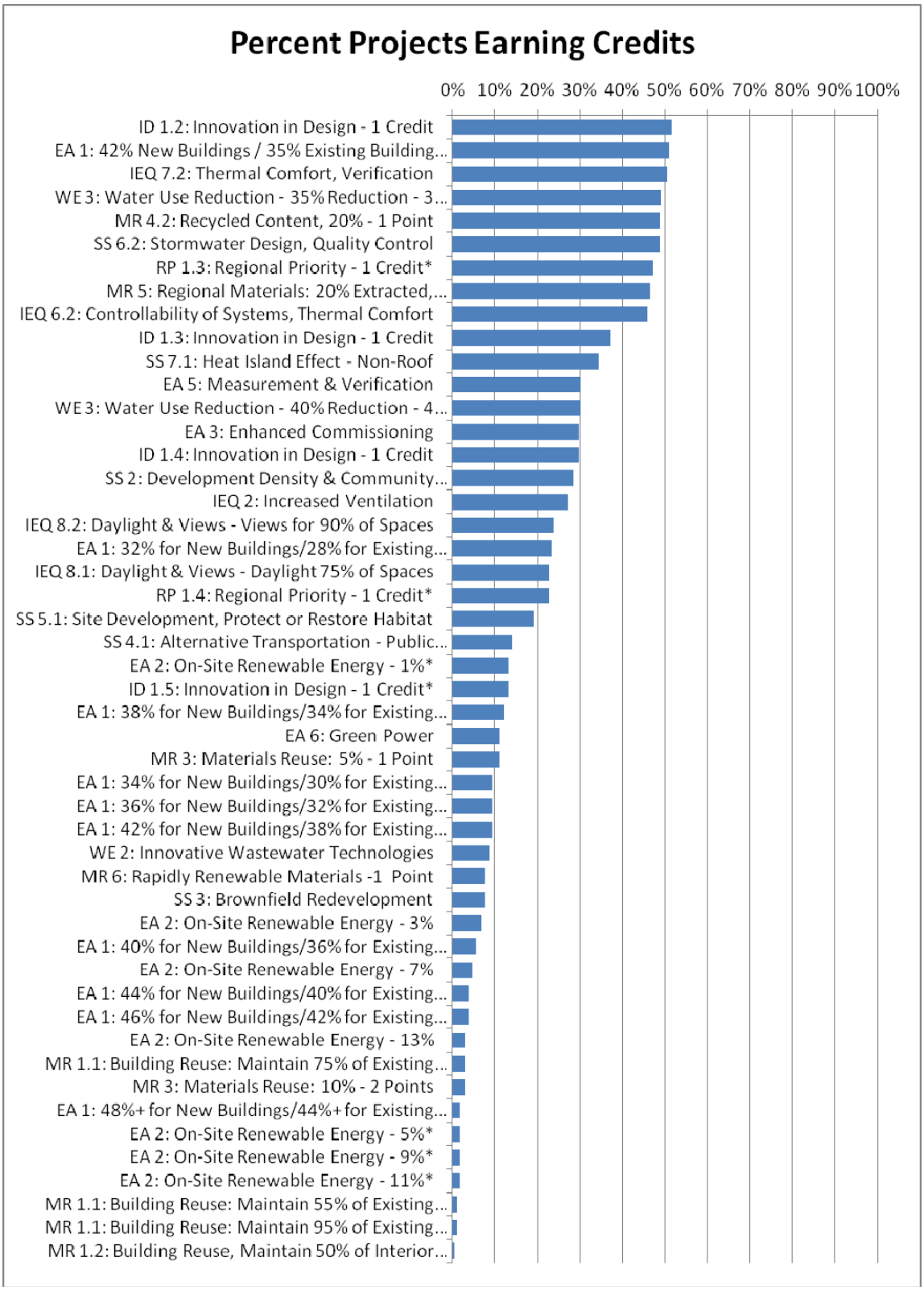
Summary

This research explored how the Air Force has implemented LEED to achieve federal and internal sustainability mandates. The purpose of this research was to determine in what way LEED has been used and why. The research methodology involved a data analysis of a project database reaching back to 2005. The database revealed a high usage of IEQ credits and a low usage of EA credits. Also, subject matter experts validated this information by citing lesser used credits as more difficult to achieve, and some of the more beneficial credits being underused. The research was limited to the project database as provided by AFCEE and the various stages of facility design and construction. Also, interview subjects are a small fraction of subject matter experts in the industry. Implications of this research suggest a more stringent system of LEED credit implementation be put into place as well as better integration of LEED throughout a project. In summary, the Air Force's implementation of LEED to meet federal and internal sustainability mandates has been marginally successful and requires further scrutiny to better provide for the military and the U.S. Government.

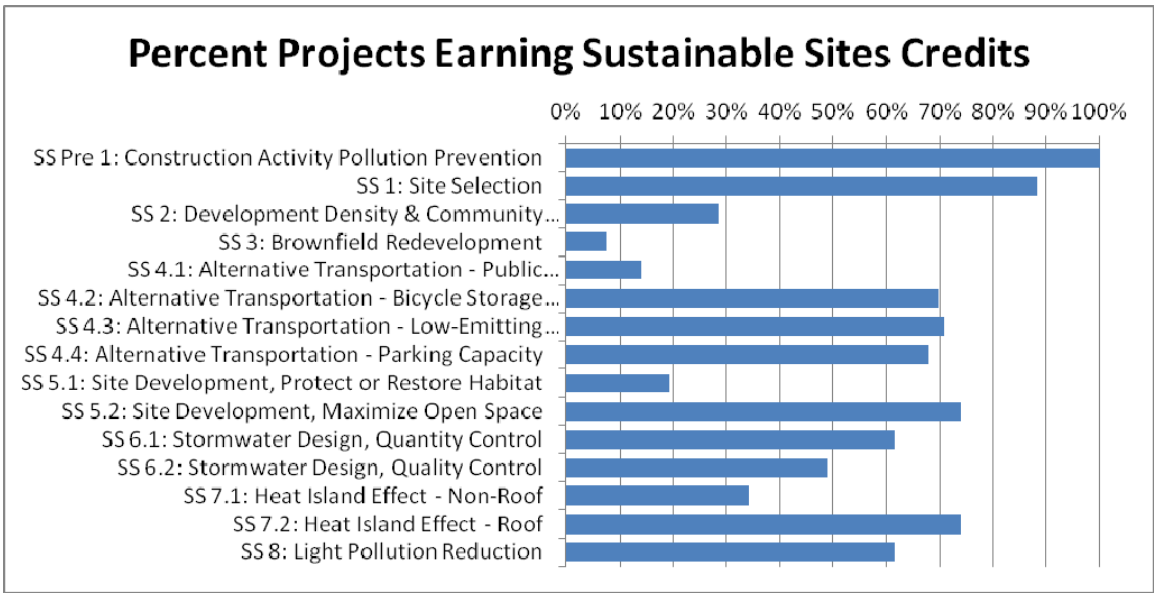
Appendix A. Earned Credit Percentages in Descending Order

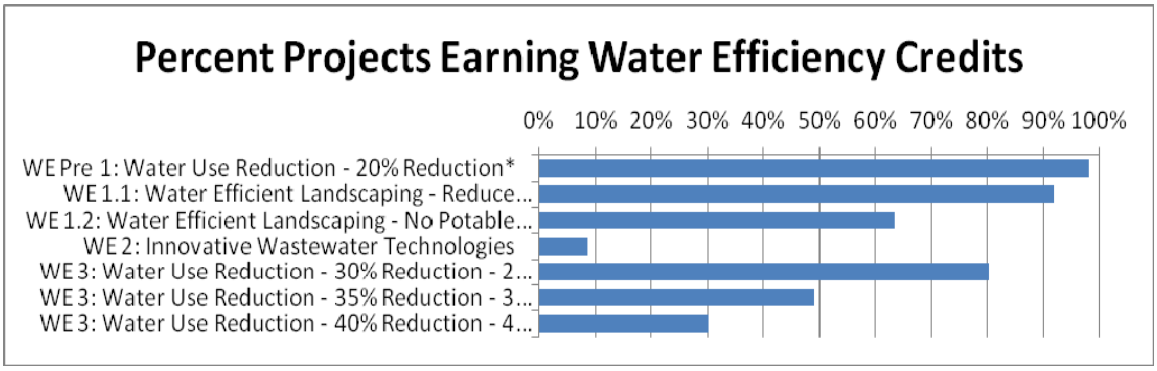


Appendix A. Earned Credit Percentages in Descending Order (cont.)

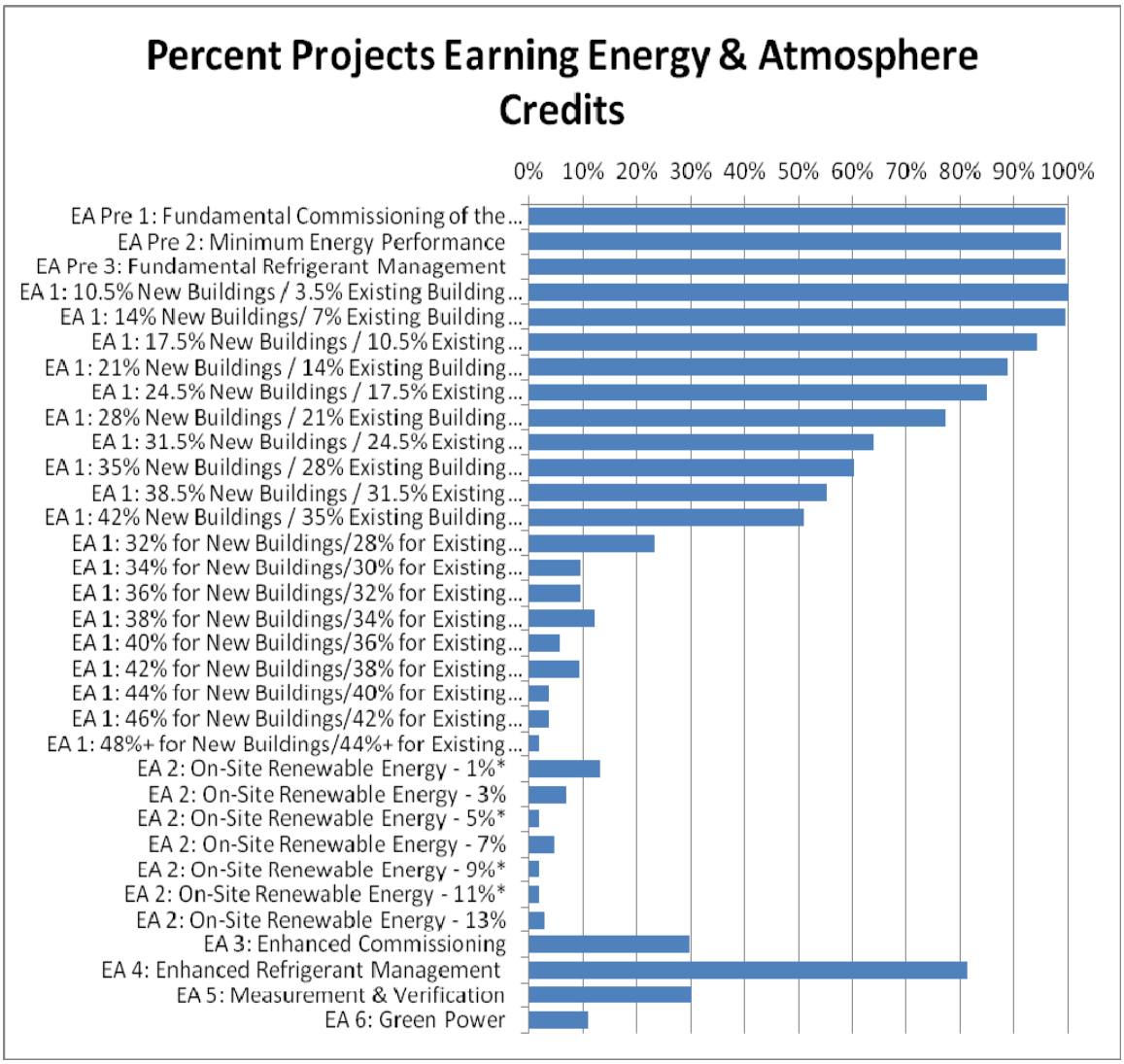


Appendix B. Earned Credit Percentages by Credit Category

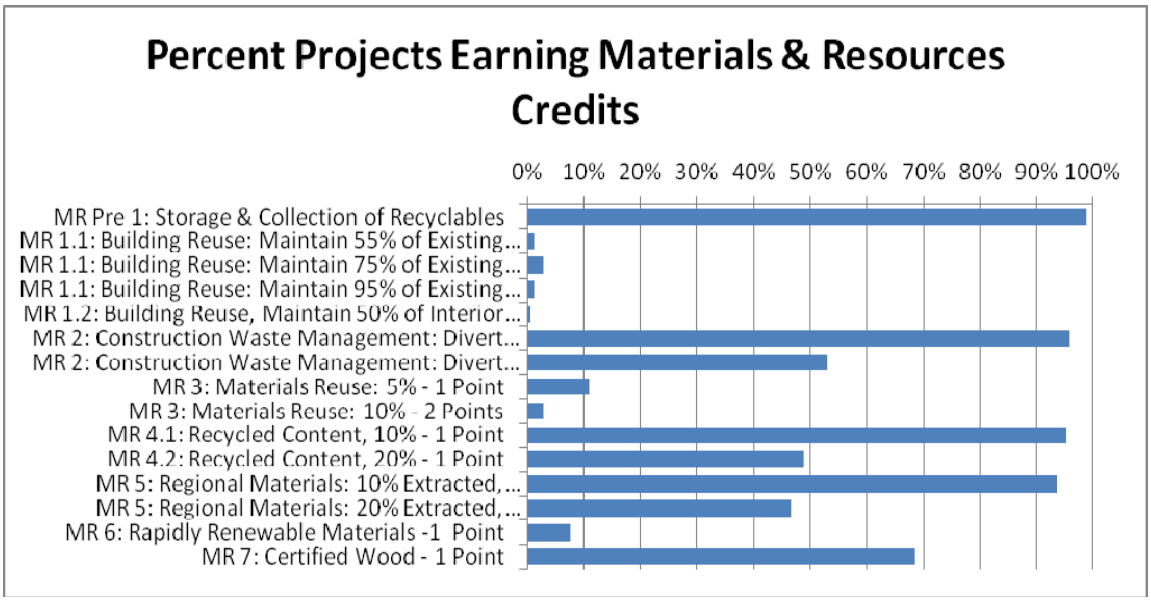


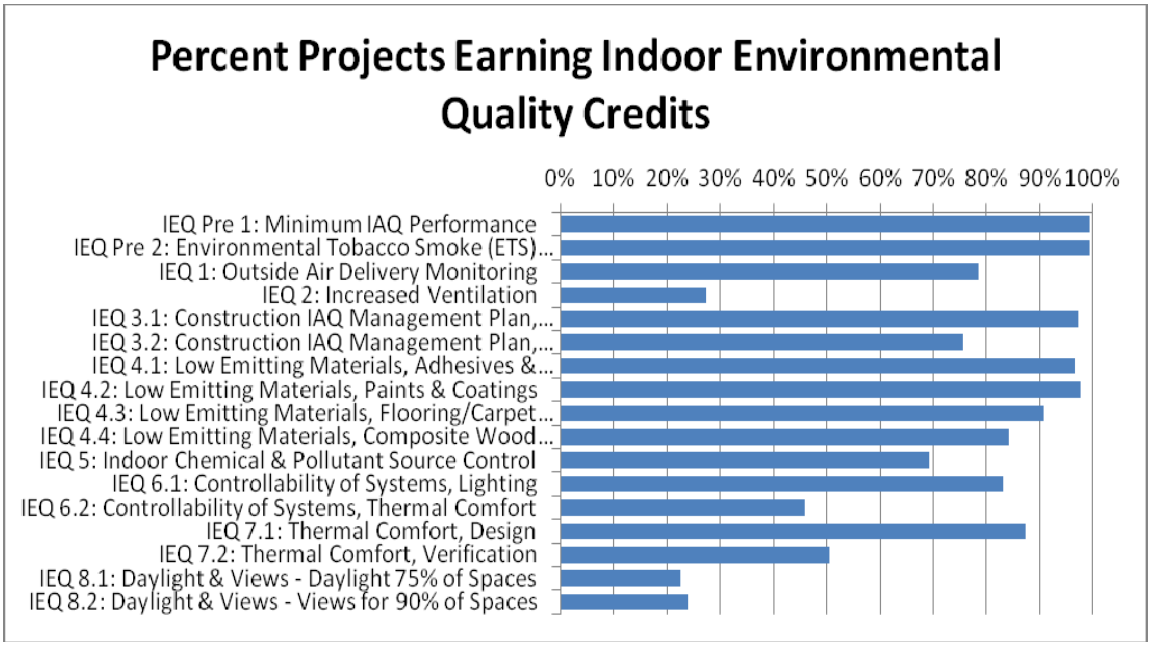


Appendix B. Earned Credit Percentages by Credit Category (cont.)

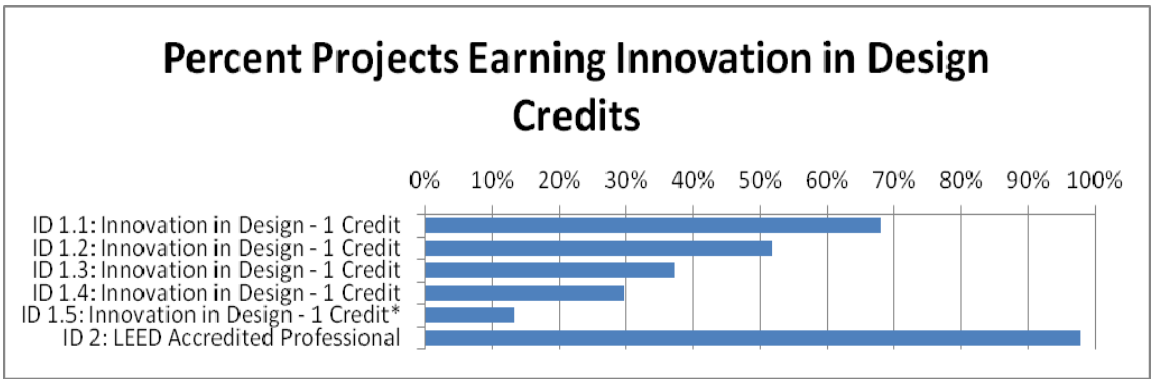


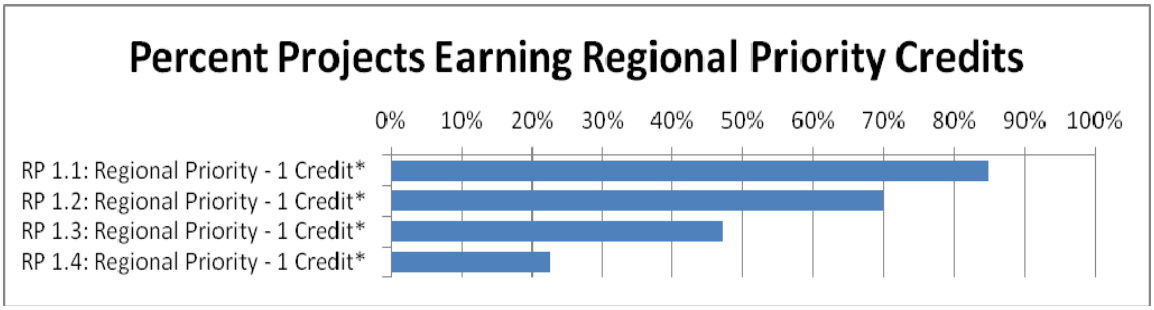
Appendix B. Earned Credit Percentages by Credit Category (cont.)





Appendix B. Earned Credit Percentages by Credit Category (cont.)





*- of 53 LEED 2009 Projects

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient

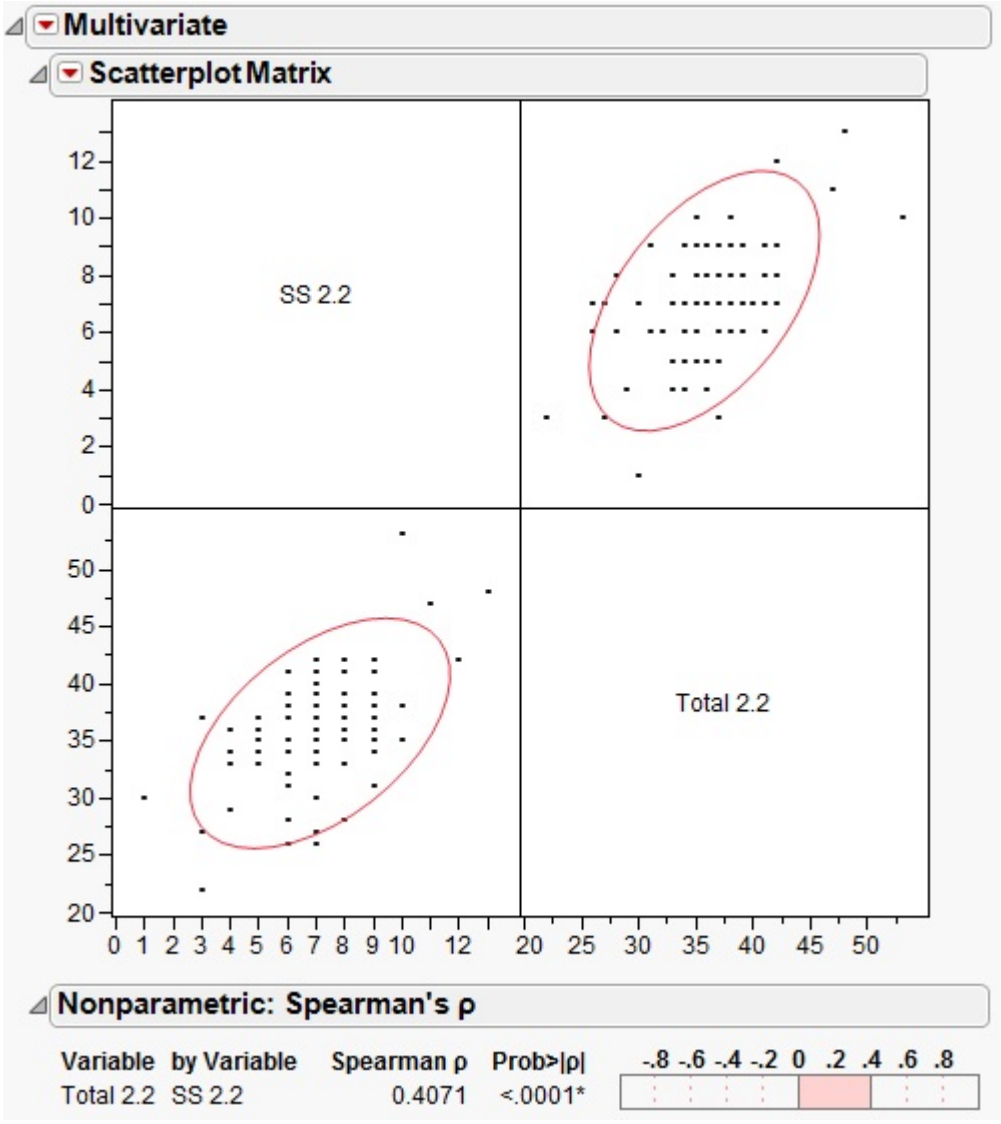


Figure C.1: JMP 9.0 Output for Sustainable Sites, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

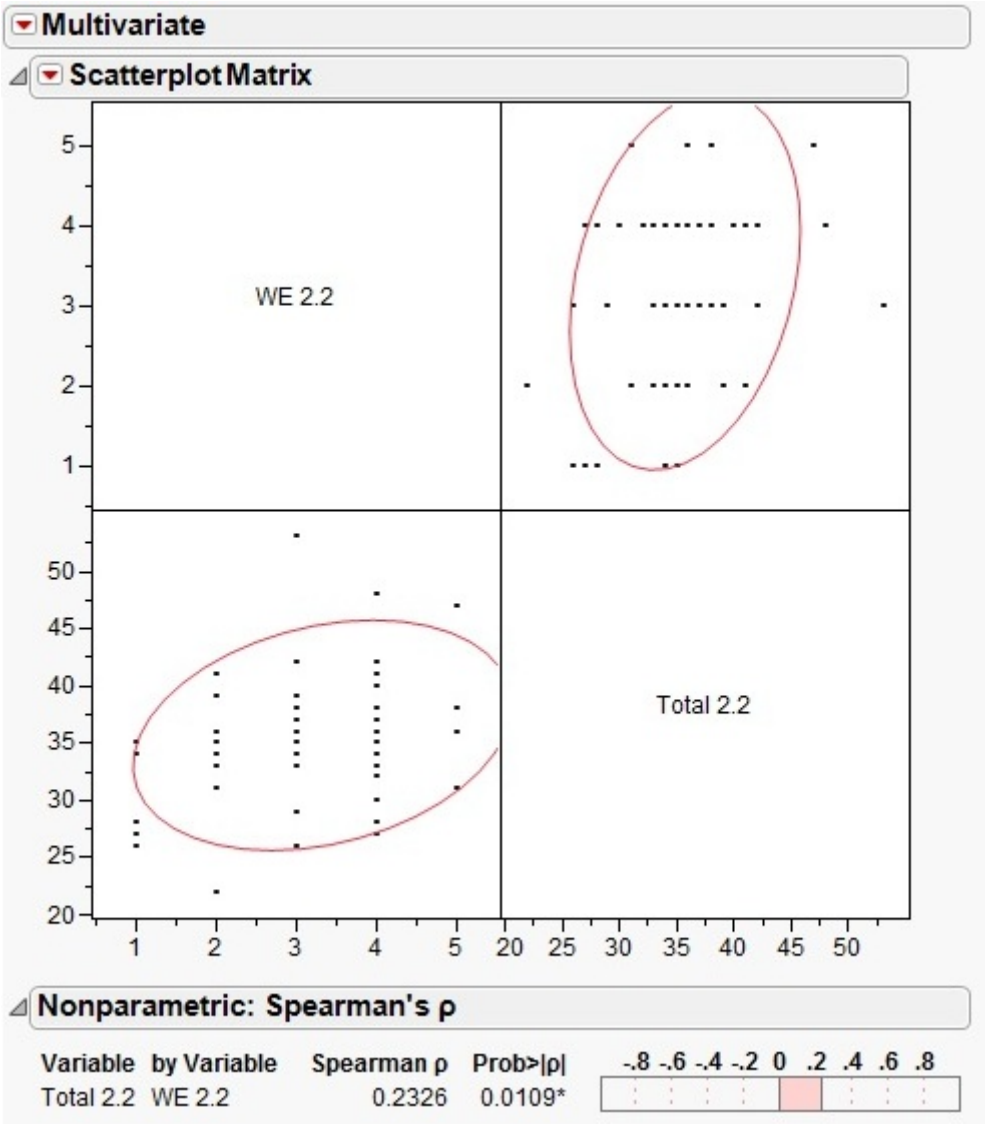


Figure C.2: JMP 9.0 Output for Water Efficiency, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

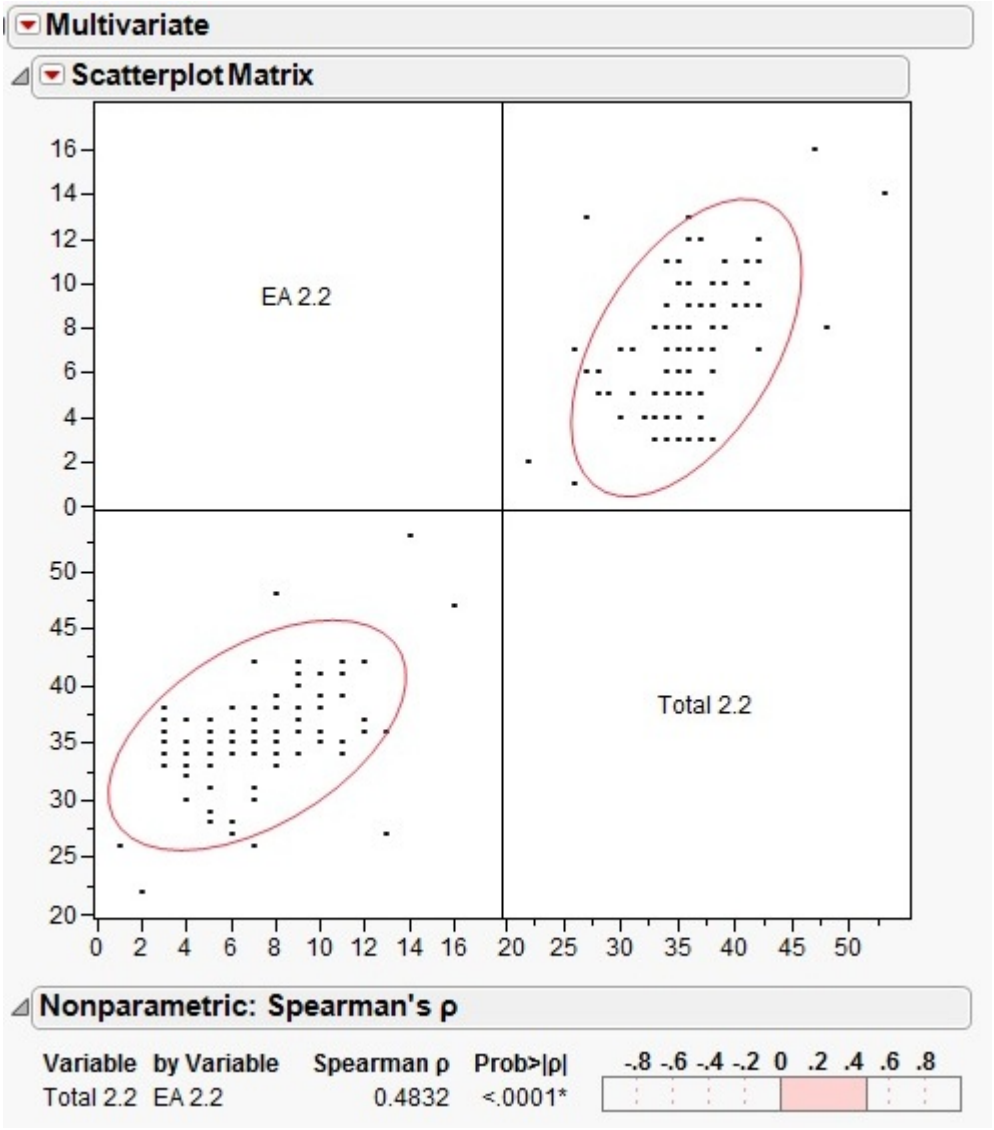


Figure C.3: JMP 9.0 Output for Energy and Atmosphere, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

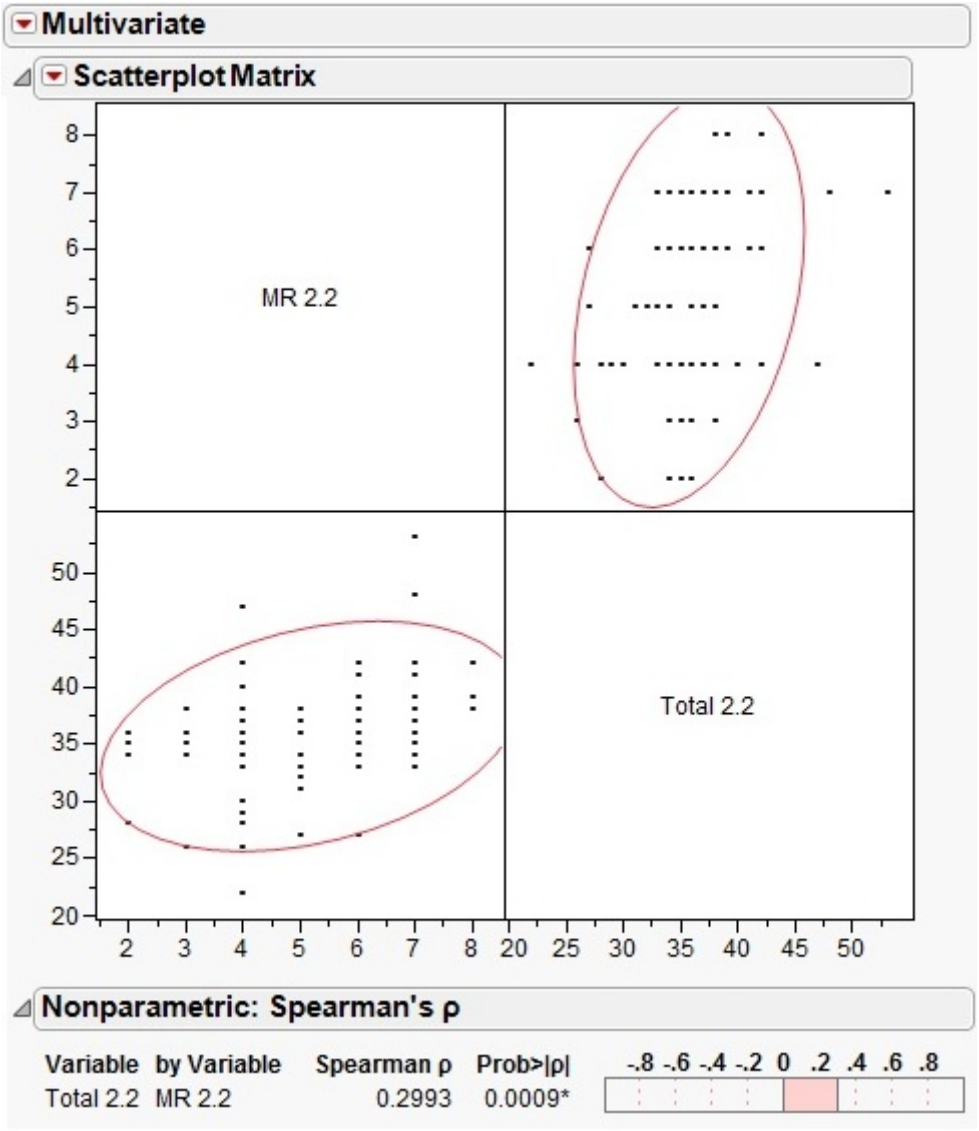


Figure C.4: JMP 9.0 Output for Materials and Resources, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

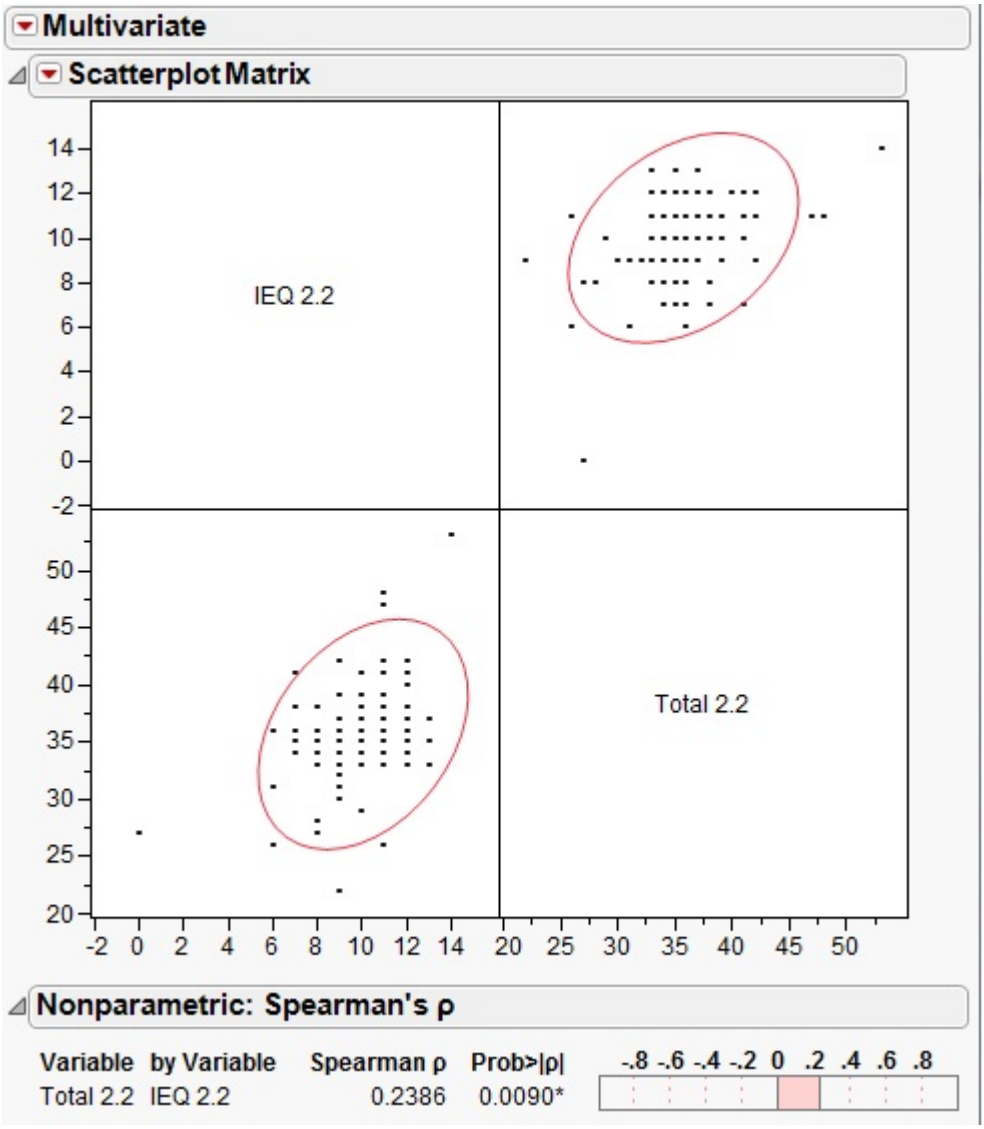


Figure C.5: JMP 9.0 Output for Indoor Environmental Quality, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

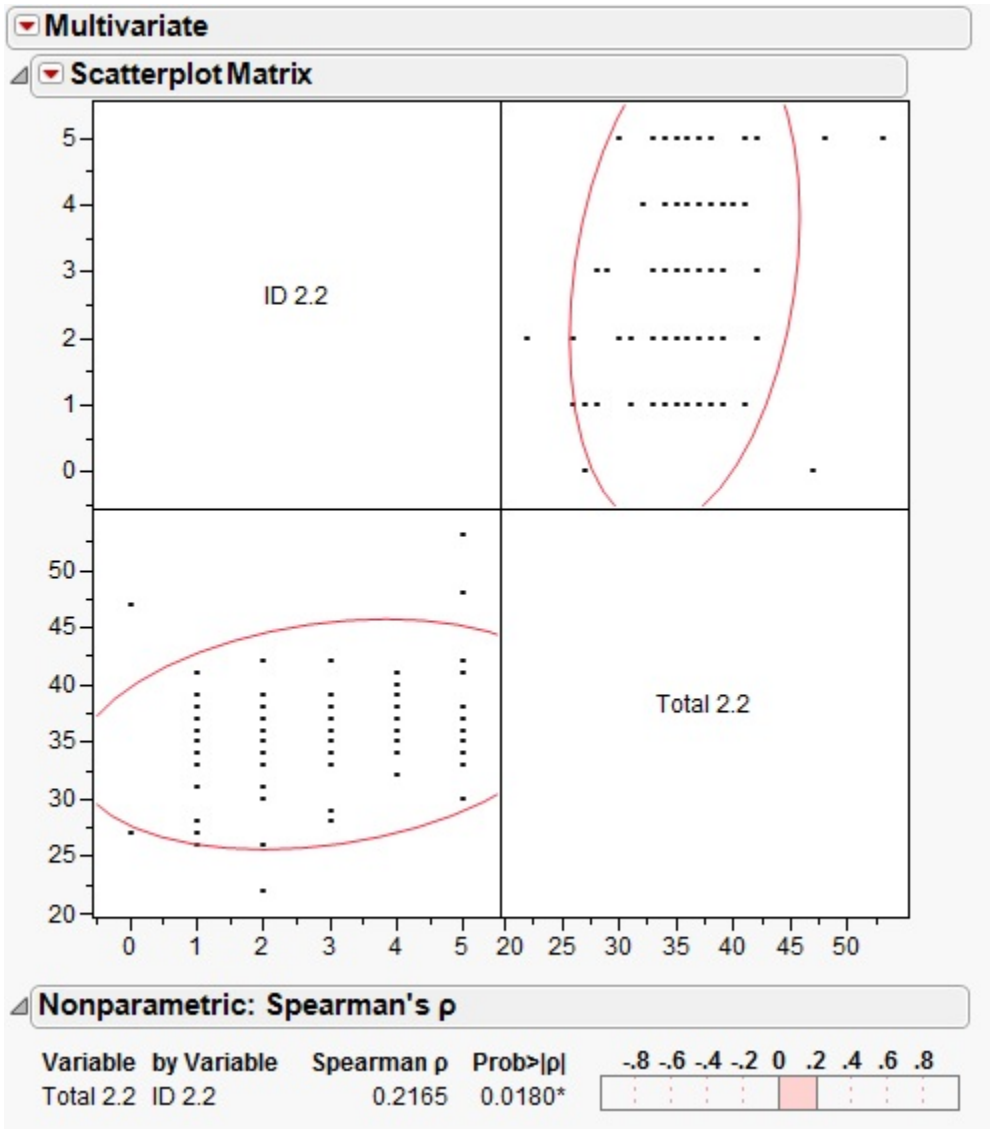


Figure C.6: JMP 9.0 Output for Innovation in Design, LEED v2.2

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

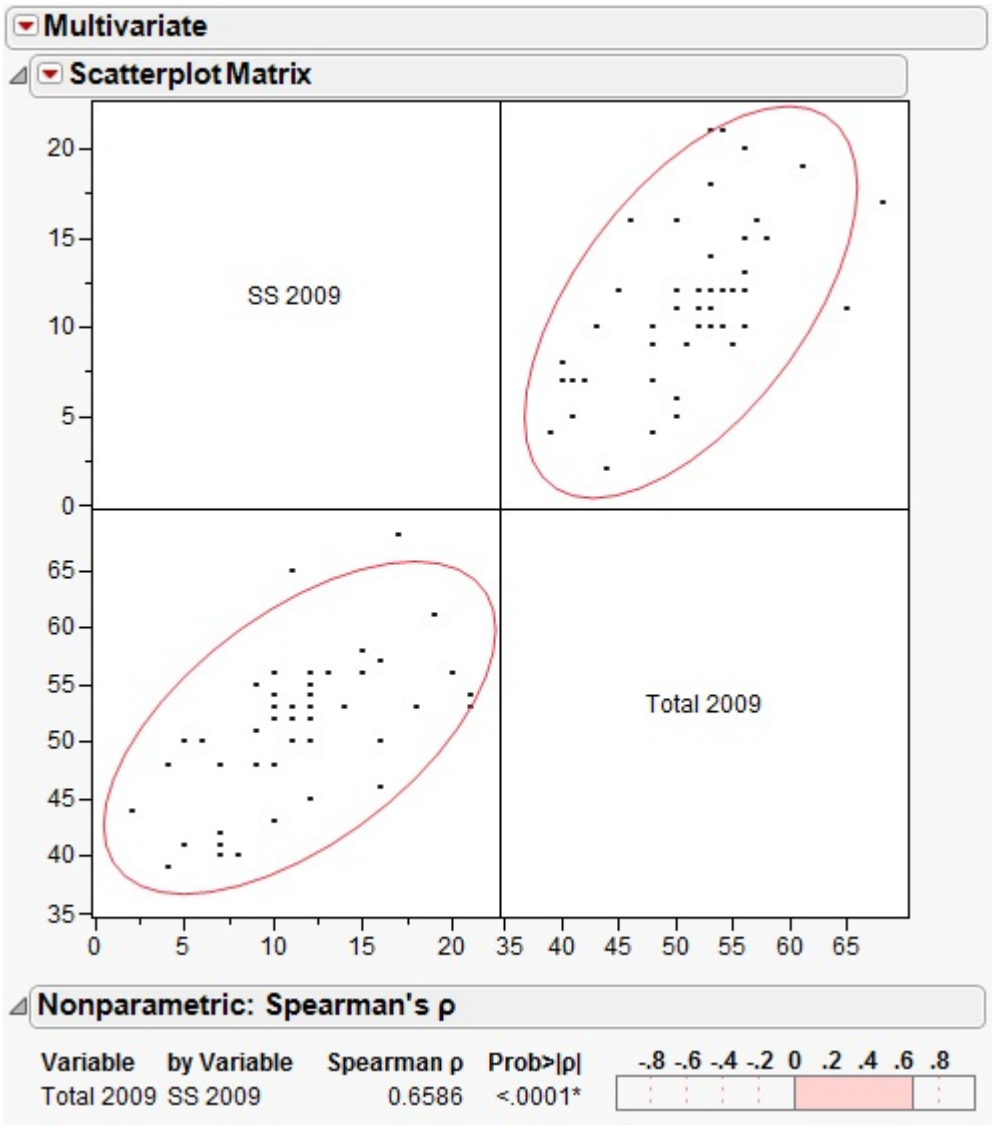


Figure C.7: JMP 9.0 Output for Sustainable Sites, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

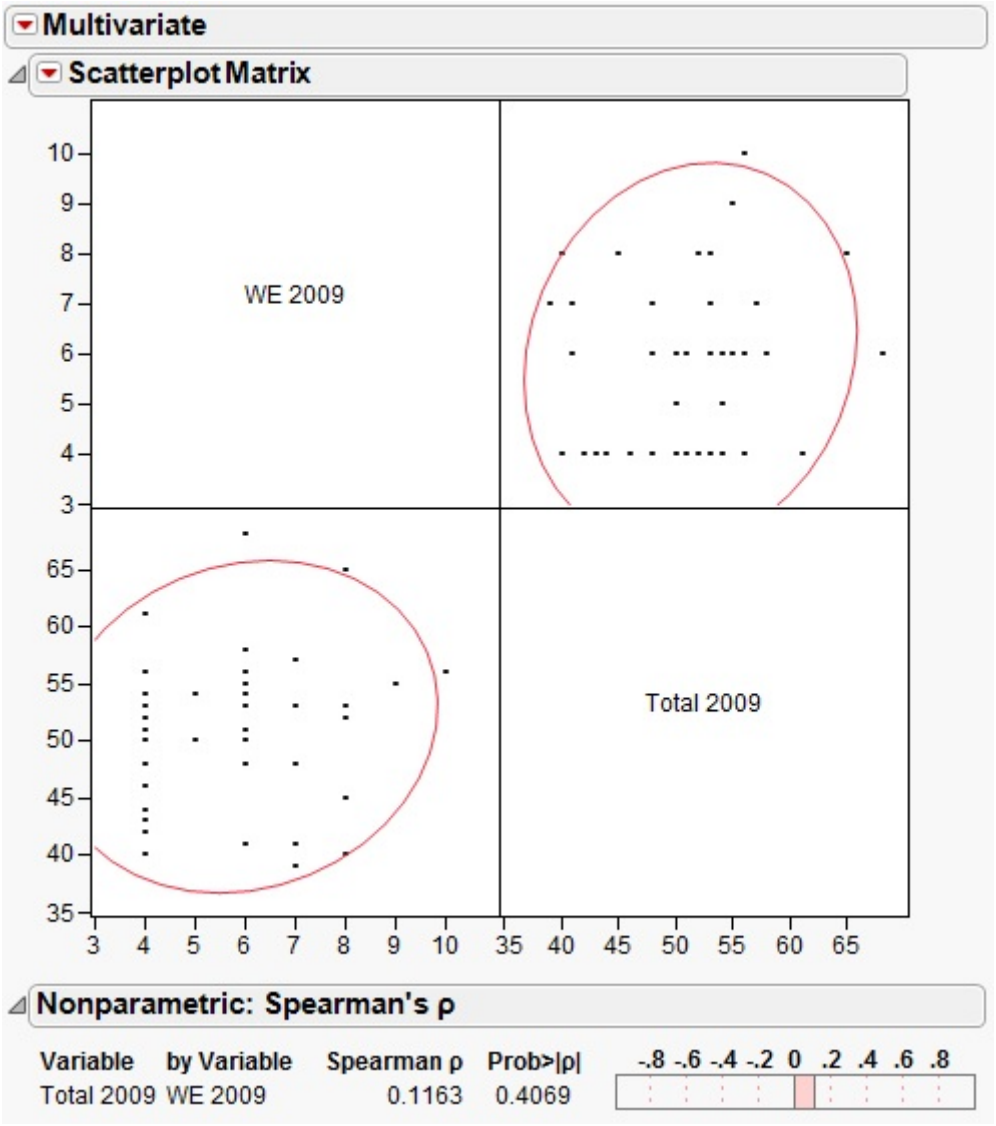


Figure C.8: JMP 9.0 Output for Water Efficiency, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

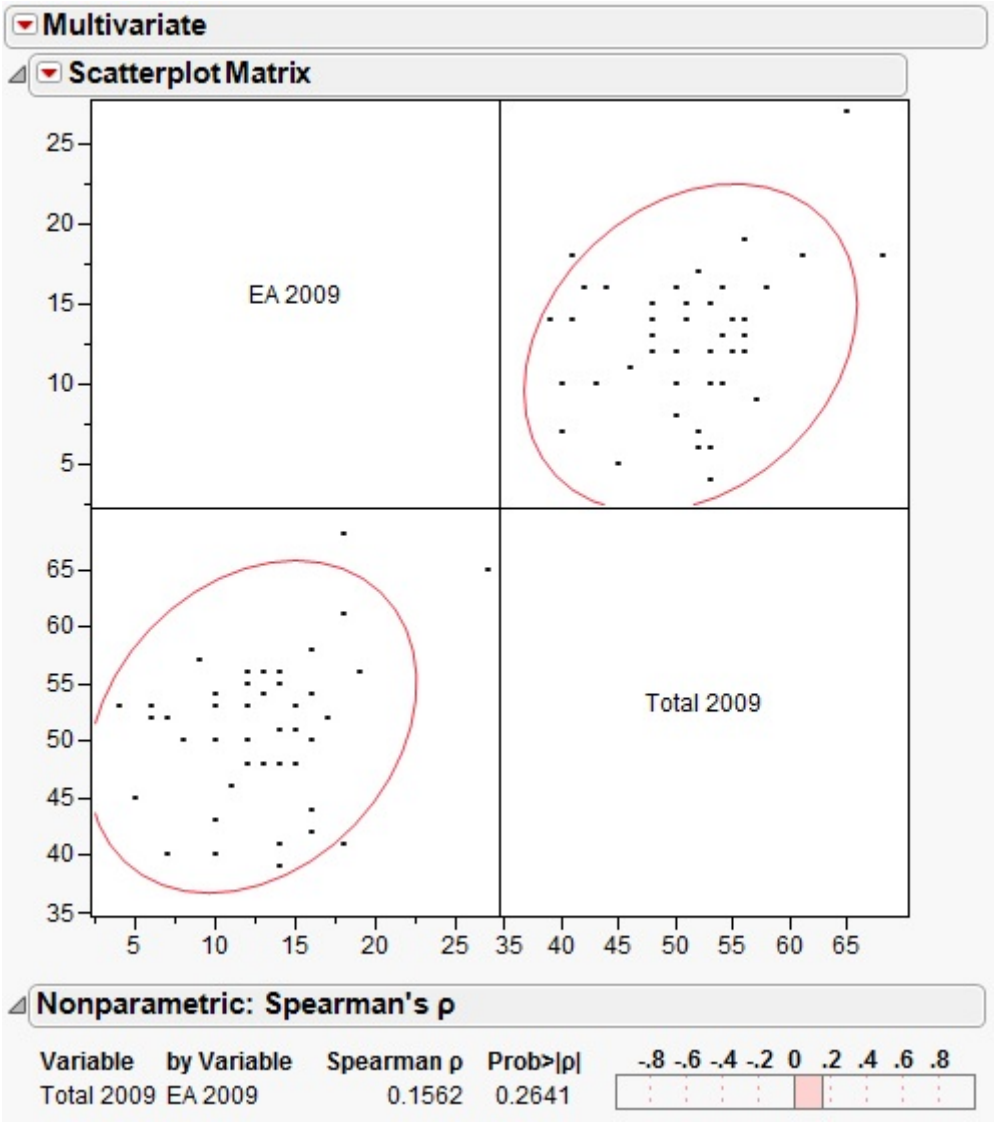


Figure C.9: JMP 9.0 Output for Energy and Atmosphere, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

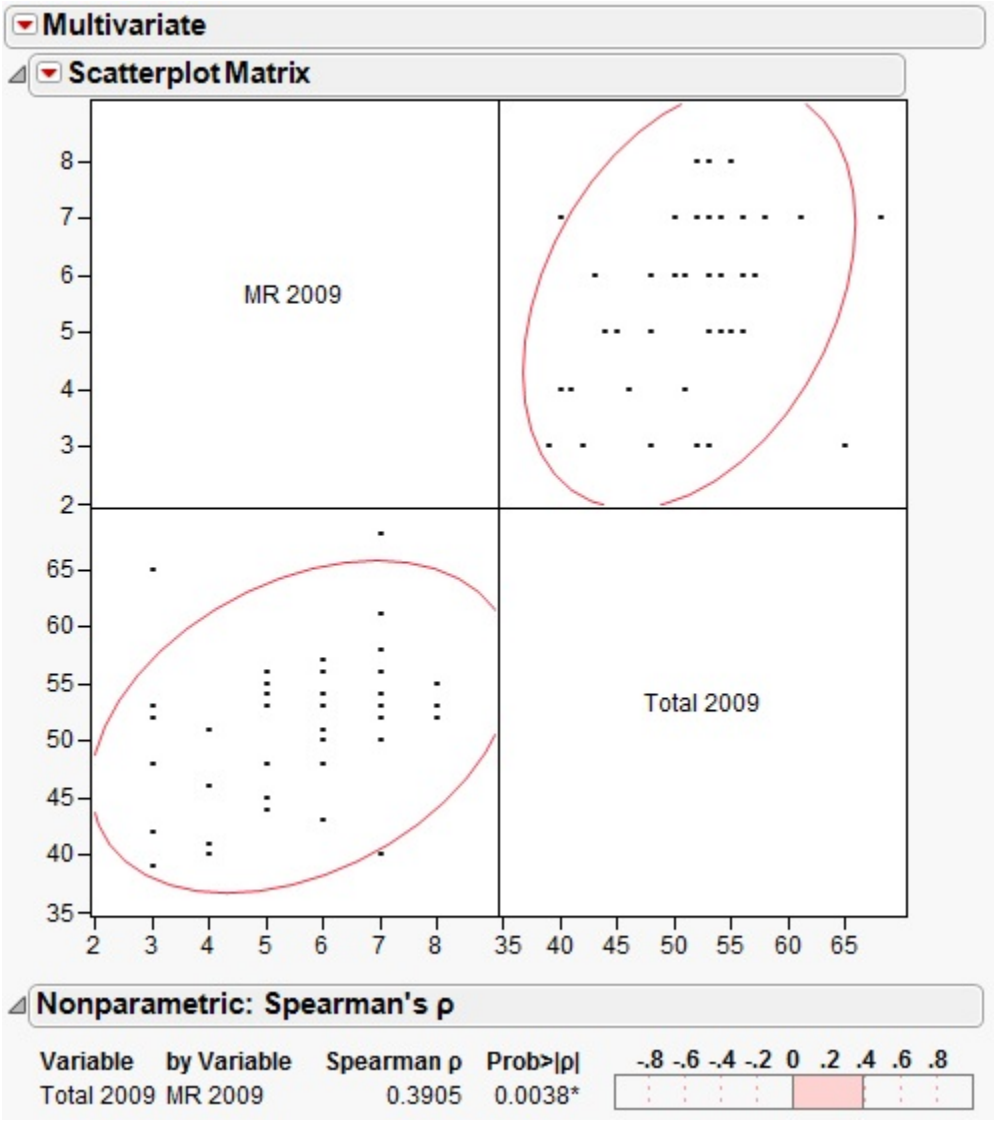


Figure C.10: JMP 9.0 Output for Materials and Resources, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

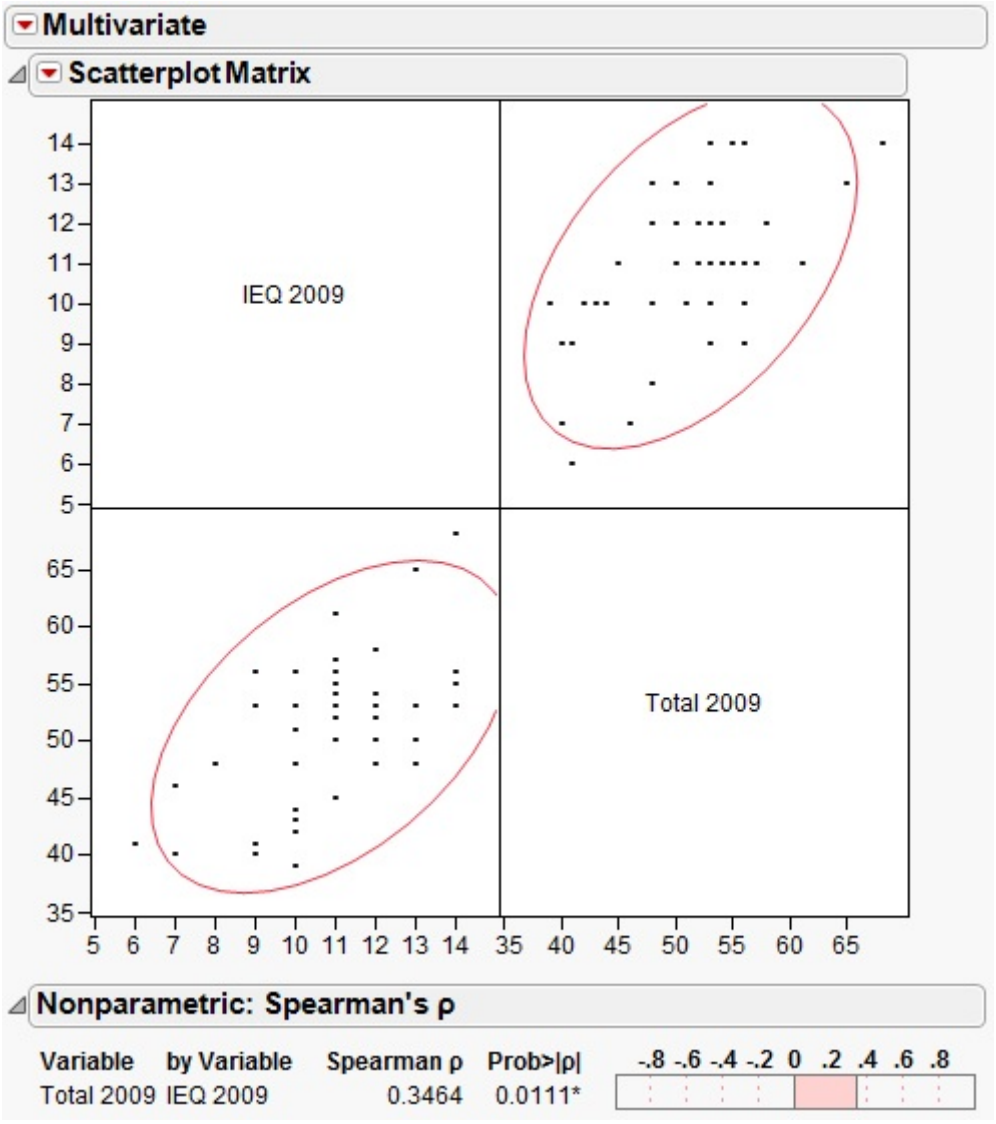


Figure C.11: JMP 9.0 Output for Indoor Environmental Quality, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

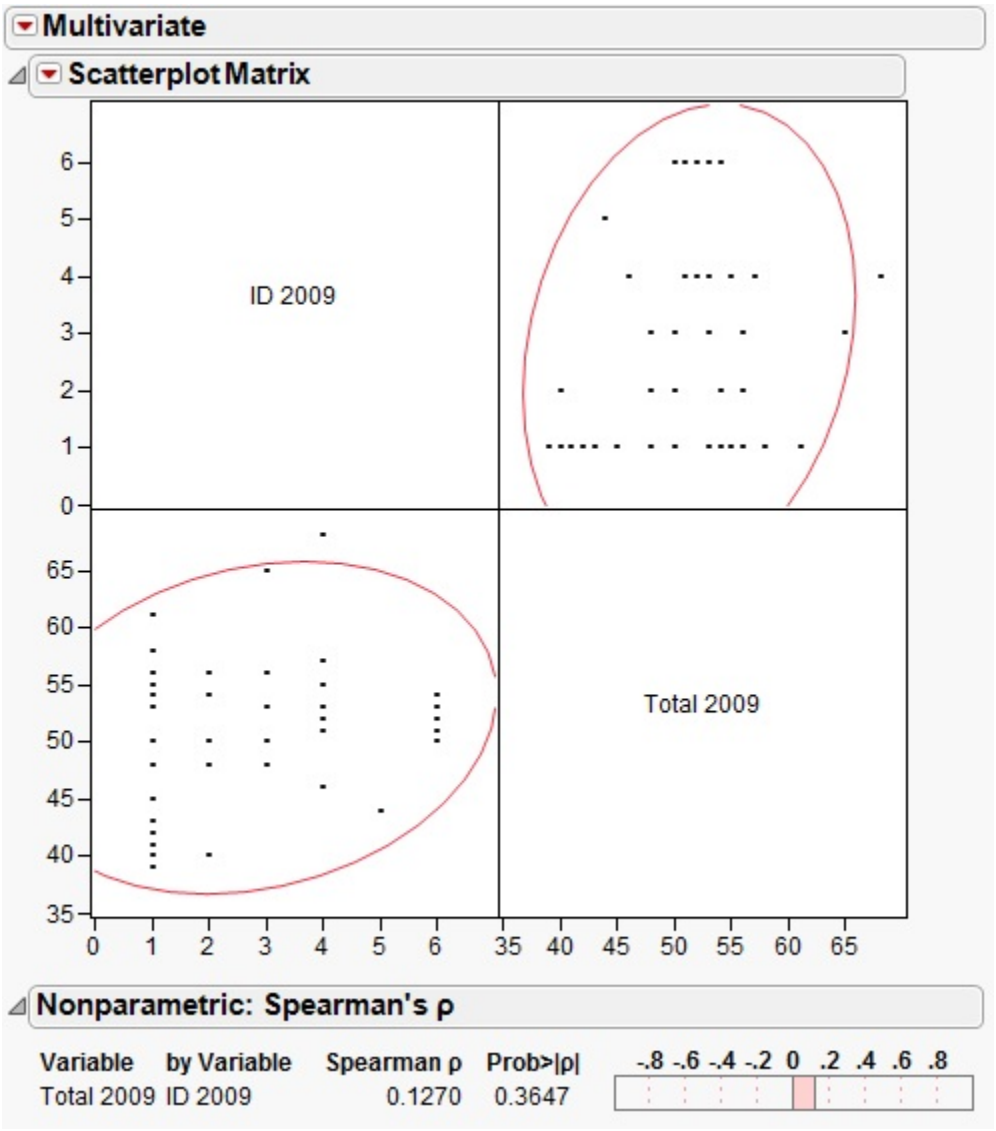


Figure C.12: JMP 9.0 Output for Innovation in Design, LEED 2009

Appendix C. JMP 9.0 Outputs for Spearman's Rank Correlation Coefficient (cont.)

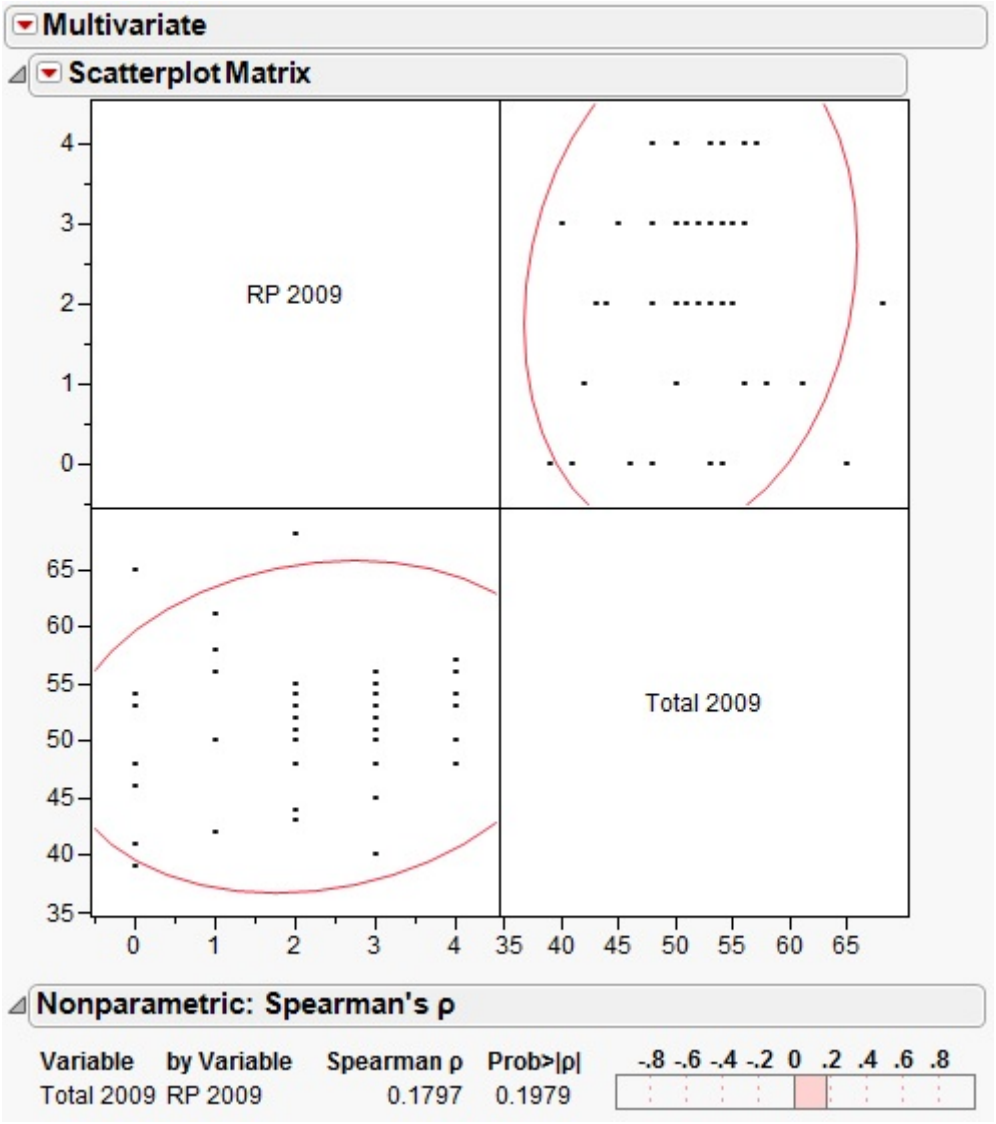


Figure C.13: JMP 9.0 Output for Regional Priority, LEED 2009

Appendix D. USAF 2011 Sustainability Memorandum Energy and Water Credits

As outlined in Attachment 1 of Air Force Sustainable Design and Development Implementing Guidance Memorandum dated 2 June 2011

Category	Credit	Points	Name
SS	7.1	1	Heat Island Effect - Non-Roof
SS	7.2	1	Heat Island Effect - Roof
SS	8	1	Light Pollution Reduction
WE	1.1	2	Water Efficient Landscaping - Reduce Potable Water Use 50%
WE	1.2	4	Water Efficient Landscaping - No Potable Use or No Irrigation
WE	2	2	Innovative Wastewater Technologies
WE	3	2-4	Water Use Reduction
EA	1	1-19	Optimize Energy Performance
EA	2	1-7	On-Site Renewable Energy
EA	3	2	Enhanced Commissioning
EA	5	3	Measurement & Verification
EA	6	2	Green Power
IEQ	1	1	Outside Air Delivery Monitoring
IEQ	8.1	1	Daylight & Views - Daylight 75% of Spaces
ID	1	1-5	Innovation in Design*
RP	1	1-4	Regional Priority*

***-When related to energy and water savings**

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14. ABSTRACT

The Air Force uses the LEED rating system as a third party verification system to ensure sustainable and resource conscious facilities. The federal government has implemented several mandates in recent years that require certain milestones be met for energy reduction, water conservation, renewable energy use, and so forth. This research aims to determine how the Air Force has implemented LEED through credit analysis and to better understand why LEED is being used in this way. Using a database of 172 military construction projects, this research evaluates the frequency of credit usage individually and by category. Interviews were conducted with subject matter experts to understand why specific credits were used, based on their ease or difficulty of achievement. Also, interview subjects were asked how to better implement LEED credits in hopes of meeting federal guidelines more effectively. The most and least frequently used LEED credits were compared with the interview results. The more frequently used credits were often easier to achieve and the less frequently used credits were typically more difficult to achieve. The final recommendation is to require a stricter Air Force guideline indicating mandatory LEED credits to align with federal policies on new military construction projects.

15. SUBJECT TERMS
green construction, sustainability, sustainable design, LEED

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